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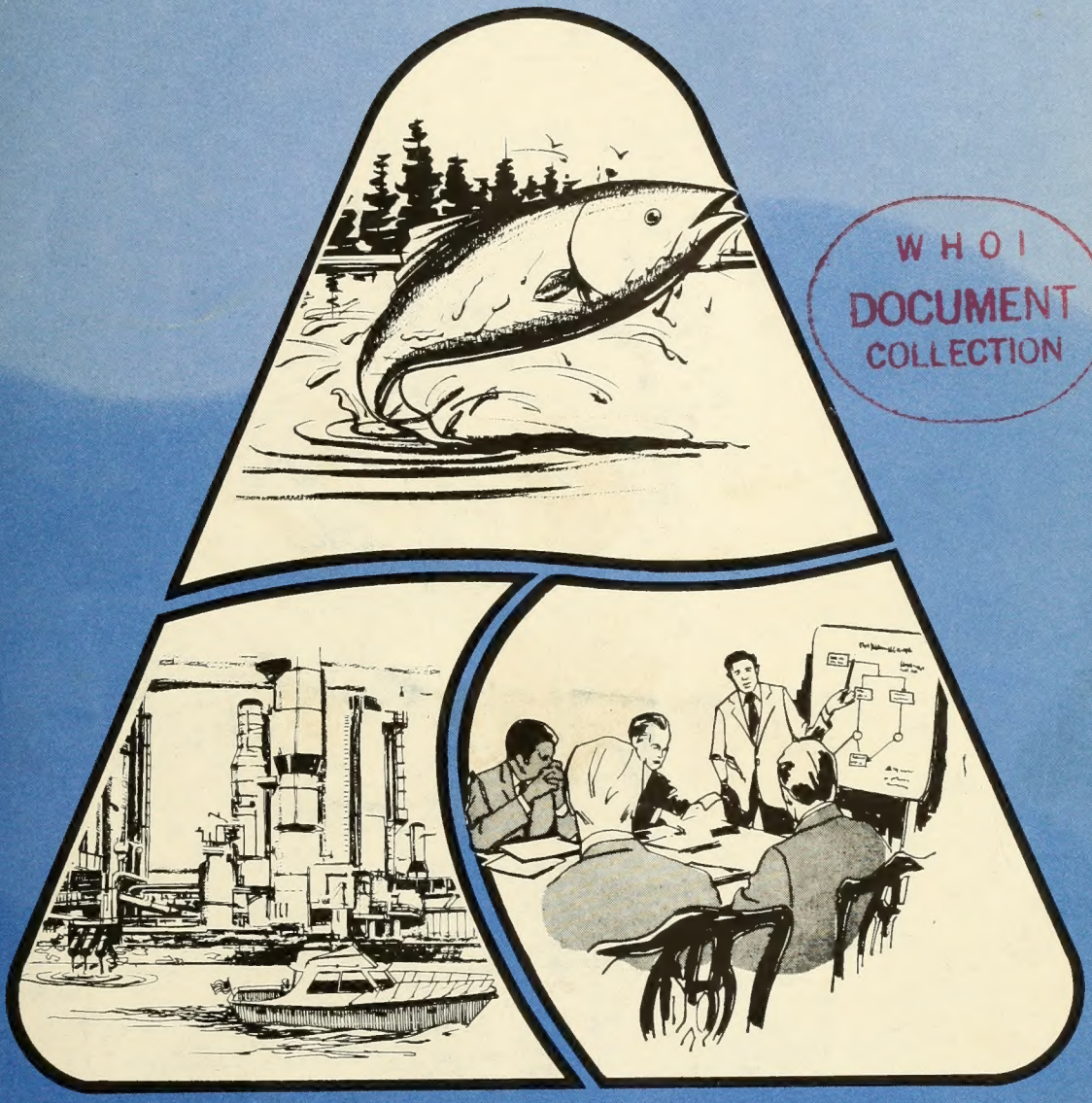

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VOLUME II

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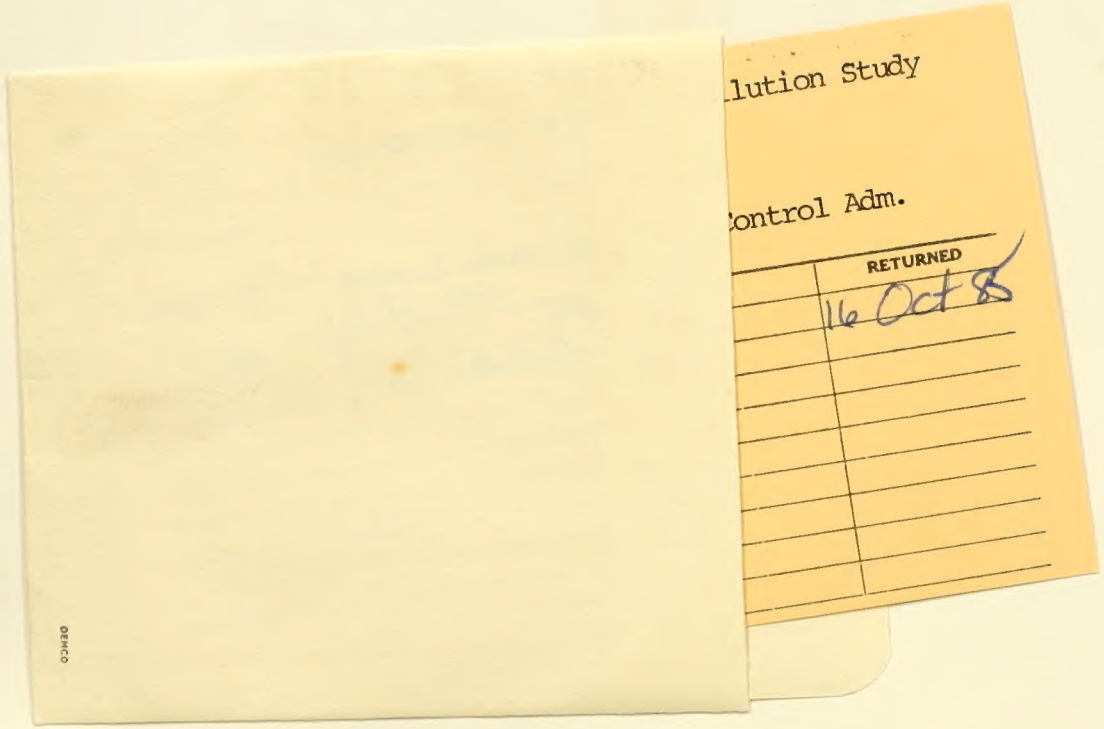
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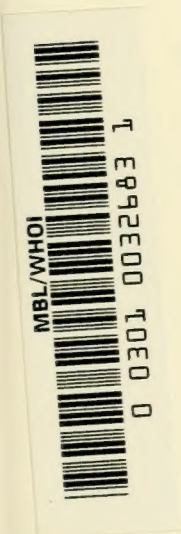
THE NATIONAL ESTUARINE POLLUTION STUDY

Volume II

A Report to the Congress



U. S. Department of the Interior • Federal Water Pollution Control Administration

NOVEMBER 3, 1969

TABLE OF CONTENTS — VOLUME II

PART IV. The Importance of the Estuarine Zone

Introduction IV-1

Chapter 1. The Estuarine System of the United States IV-3

Section 1. General Description IV-5

Section 2. The Dominating Environmental Factors IV-10

Section 3. The Biophysical Estuarine Regions IV-42

Section 4. The Land and the Water IV-52

Section 5. The Life IV-76

Section 6. Energy and Management in the Biophysical Environment IV-91

Chapter 2. Use of the Estuarine Zone IV-95

Section 1. Sustenance: Use as a Fish and Wildlife Habitat IV-96

Section 2. Enjoyment: Use for Recreation IV-114

Section 3. Use for Transportation IV-124

Section 4. Use as a Human Habitat IV-130

Section 5. Deliberate Modification of the Estuarine Zone IV-141

Section 6. Summary IV-149

PART IV. (continued)

Chapter 3. The Social and Economic Values of the Estuarine Zone IV-153

Section 1. Economic Development of the Estuarine Zone IV-155

Section 2. The Values of Individual Uses IV-165

Section 3. Reviews of Case Studies of Uses of the Estuarine Environment IV-179

Section 4. Measures of Value and Importance of the Estuarine Zone IV-246

Chapter 4. Social and Economic Trends IV-251

Section 1. National Population and Economic Trends IV-253

Section 2. Trends in the Estuarine Zone, Population and Economic IV-263

Section 3. Trends in Selected Activities Associated with the Estuarine Zone IV-290

Section 4. Future Waste Discharge Impacts IV-331

Chapter 5. Pollution in the Estuarine Zone IV-349

Section 1. Materials and Conditions that Degrade the Environment IV-351

Section 2. Sources of Pollution IV-381

PART IV. (continued)

Chapter 5. (continued)

Section 3. Extent of Pollution Effects IV-403

Section 4. Examples of Estuarine Systems Damaged by Pollution IV-414

Section 5. Conclusions IV-429

Chapter 6. Use Conflicts and Damages IV-433

Section 1. Nature of Use Conflicts IV-434

Section 2. Examples of Use Damage IV-447

Section 3. Trends in Estuarine Ecology Associated with Man's Activities IV-488

Section 4. Resolution of Use Conflicts IV-500

Section 5. Summary IV-507

Chapter 7. Summary IV-509

Section 1. The Biophysical Environment IV-511

Section 2. The Socioeconomic Environment IV-532

Section 3. Pollution: The Impact of Human Society on the Estuarine Environment IV-557

Section 4. Use Conflicts and Damages: Man's Battle with Himself and Nature IV-568

Part IV
IMPORTANCE OF THE ESTUARINE ZONE

PART IV

INTRODUCTION

The comprehensive management program presented in Part III establishes a framework to regulate man's activities in the estuarine zone to preserve and develop the estuarine resource while achieving full use of it. Effective management, however, must be firmly based on an understanding of what the estuarine resource is, what use it has to man, and what impact man's activities have on it.

The comprehensive management program is in essence a working relationship among the institutional, biophysical, and socioeconomic environments in the estuarine zone. This Part of the report deals with the existing relationship between the biophysical environment and the socioeconomic environment. It describes first the estuarine zone without man: then it considers how man uses the estuarine zone and how these activities affect the land, the water, and the life. Finally, it seeks to show what will happen to the estuarine zone unless man controls his impact on this part of his environment.

The biophysical environment divides naturally into ten geographical regions, each dominated by a different combination of environmental conditions. The discussion revolves about these biophysical regions as the primary subdivisions of the natural environment of the

estuarine zone. Because of the similarity of environmental conditions within it, each region has estuarine systems, uses, and problems which are typical of the region, if not unique to it.

The use of the biophysical regions as the basic units for discussion illustrates regional similarities and differences. These serve not only to point out the essential unity of the estuarine zone as a unique resource, but also to emphasize how an effective national management program can use knowledge gained in one region to solve problems in another.

Certain photographs of a purely illustrative nature, and not essential to the continuity of the text, have been omitted in this part of the report as presently duplicated.

Chapter 1

THE ESTUARINE SYSTEM OF THE UNITED STATES

Man uses and is influenced by the whole world ocean, but that narrow zone where the land containing his civilization meets the sea is unique. This is the point where man, the sea -- his immemorial ally and adversary -- and the land meet and challenge each other. That narrow zone is the subject of this chapter (IV-1-1).

The estuarine zone has many forms; nearly all are represented along the coastline of the United States. These include the classic drowned river mouth, exemplified by Delaware Bay and in greater variety by its neighbor, Chesapeake Bay. There are the entrance cuts and deltas of great rivers such as the Columbia and the Mississippi; there are the marshlands of Georgia and the barrier island systems of North Carolina. There are the coral formations of the Florida Keys and the fjords of Alaska and Washington; there are the rocky coast of Maine, the bluffs of California, and the sandy shores of Texas. There is infinite variety but there is also the common theme of the sea, the land, and along much of the United States coastline -- man.

The estuarine zone of the United States was the gateway to a continent. The many deep, natural harbors of the Atlantic and the Gulf coasts provided safe anchorages for the ships which brought the first colonists to these shores and which carried the produce of the land to distant markets. The teeming coastal waters provided a never-failing supply of food to vary and supplement the results of farming and hunting.

The great population and industrial centers which developed around these seaports served as supply bases and take-off points for those who moved west, north, and east to settle the enormous heartland of North America, leaving the estuarine zone and its problems far behind, but still using this zone to send their produce across the sea.

This zone between land and sea is a unique environment deriving its properties from both land and sea, but having characteristics resulting from the existence of the interfacial zone itself and from the interaction of land and sea upon each other.

SECTION 1. GENERAL DESCRIPTION

The estuarine zone is best characterized as a region of constantly recurring change. The constancy of change and the dynamic equilibrium associated with the changes comprise the visible features of the estuarine environment. The obvious complexity of structure, movement, and life in the estuarine zone hides the inherently simple basic causes of the existence and character of the estuarine environment.

All life is dominated by gravity and by the sun's radiant energy, but the effects of these are especially apparent in the estuarine zone. The earth's gravity pulls the rivers down to the sea; at sea level the gravitational attraction of the earth itself reaches a dynamic balance with the gravitational attraction of the sun and the moon. The results of this are the unique estuarine water movement patterns caused by the differences in density between fresh river water and salt ocean water, and the tidal ebb and flow which is noticeable only in the estuarine zone.

All forms of life on earth depend on the sun as their ultimate source of energy. This energy is incorporated into plant material which in turn supports all animal life. Plants need water and light to grow. There is a profusion of both in the estuarine zone together with a plentiful supply of dissolved nutrients derived from both land and sea. These conditions make coastal areas the most productive environments in the world, and as a result very specialized biological communities have developed in the estuarine zone. Such communities

can not only tolerate the dynamic balance of conditions but actually depend on the constantly recurring environmental variations to sustain themselves.

The wide range of interaction of the two basic driving forces of gravity and solar energy brings about a bewildering variety of individual environments in the estuarine zone, each being dominated and controlled by a different combination of factors. Some may be dominated by tidal range, some by river flow, some by geometry of the coastline, some by climate, some by the sediments deposited, and some by combinations of these. The variety is infinite.

Yet, within this variety, there is order which lends itself to measurement and through measurement to management of the estuarine zone to preserve it for continuing multiple use. The purpose of this discussion is not to present a detailed analysis of the differences among the parts of the estuarine zone, but rather to outline what these differences are, why they exist, and what must be measured to establish a basis for sound technical management within the overall framework of wise institutional management.

It would be convenient if the state of knowledge were such that the estuarine environment and its variety could be described in terms of the primary forces which control it; then it would be possible to manage each estuarine system efficiently and exactly for optimum use.

Unfortunately, the present extremely limited state of knowledge requires the measurement of a wide variety of attributes, and management must be derived through the pragmatic application of knowledge gained from such measurement.

There are six different kinds of characteristics that should be understood to make a rational effort at sound technical management:

Shape and Size. Fresh water carries sediments eroded from the land to the coast where they are deposited and molded along with the original shoreline by the energy of ocean waves and currents. Shape and size go far toward determining water movement, the life forms present, and the speed with which pollutants can be absorbed or passed through the estuarine zone. These are characterized by length of shoreline, water and marsh area, and water volume.

Water Movement. The slight difference in density between fresh water and ocean, combined with tidal, weather, and shape effects, causes diversity of water movement patterns in the estuarine zone. These patterns are important in pollution control and in determining the ecological balance. Parameters of water movement are river inflow, tidal range, currents, density difference, and volume of tidal inflow.

Life Forms. The estuarine zone is recognized as the most productive part of the natural environment. The many forms of life include

animals and plants which live in the bottom, on the bottom, in the water, on the water, and in the marshes which border much of the coast. The various communities in the estuarine zone are characterized by measuring the identity, distribution, and abundance of the species present, ranging from bacteria and the minute phytoplankton which are the primary users of solar energy to the fish, shellfish, and other wildlife which are the final steps in the food chain concentrating solar energy for man's use.

Water Quality. Even raw domestic sewage is over 99 per cent pure water, but the infinitesimal amount of dissolved and suspended material has effects far out of proportion to its magnitude. While ocean water contains dissolved solids measured in concentrations of "parts per thousand," water quality measurements, except for temperature, are couched in terms of "parts per million" and "parts per billion" whether they are measurements of dissolved oxygen, plant nutrients, organic pollutants, toxic chemicals, or any of the other parameters by which pollutional levels are characterized.

Upon the very delicate tests by which such minute concentrations are measured depends the quantitative knowledge of pollution and how to control it.

Nature of the Bottom. The land under the water in the estuarine zone can tell much of the history of the water flowing over it. Solids are deposited from the water on the bottom, and creatures

and plants living on and in the bottom draw their nourishment from the water itself. Estuarine bottoms are characterized by the kind and amount of sediments, vegetation, and animal life found there, both near the surface and much deeper.

Aesthetic Appeal. Not all people enjoy the same things: the bustle of the Port of Baltimore might not be appreciated by a salmon fisherman from Alaska, for example, nor might a shrimp fisherman from the marshes of Louisiana appreciate the bluffs along the California coast. Yet an estuary which has no debris along its edge or floating in it, no smell of oil, or chemicals, or sewage, no dead fish, no floating mats of algae, and no peculiar color is pleasing to all. These things are generally subjective, and since they do not lend themselves to quantitative measurement, are sometimes overlooked in evaluating the quality of the estuarine environment.

Through measurement of these six kinds of characteristics, the dominating environmental factors in the estuarine zone can be understood and made to work for the ultimate benefit of mankind.

SECTION 2. THE DOMINATING ENVIRONMENTAL FACTORS

The diversity of the estuaries, bays, inlets, lagoons, marshes, and other features which make up the estuarine zone presents a disconcerting picture of apparent individual uniqueness and complexity without evident unifying principles for technical and political management. Such unifying principles do exist, however, and the estuarine zone as an environment is governed by a small number of often competing dominating factors, having interrelationships which determine the nature of each individual estuarine system. Similarities and contrasts among estuarine areas in different parts of the coastline point out the limitations of technical management in the various portions of the estuarine zone, and show the realities of nature within which the managing political entities must work.

CONTINENTAL SHELF

The submerged land next to the continent slopes gently to a depth of about 600 feet, then it drops more rapidly to form the deep ocean basins (see Figure IV.1.1). This fringe of slightly sloping submerged land, which along much of the Atlantic and Gulf coasts would appear quite flat to the naked eye, is called the "continental shelf," and its width and general configuration along the coastline of the United States is one of the offshore conditions affecting the estuarine environment.

FIGURE IV.1.1 MAJOR OCEAN CURRENTS AFFECTING THE UNITED STATES

The large ocean waves lose much of their energy in the relatively shallow water depths over the continental shelves, thus reducing the force with which they strike the shore (Figure IV.1.2). Where the continental shelf is wide, waves reach the shore with greatly decreased power and tend to move existing sediments around rather than cutting the shoreline to produce new ones.

Along the Atlantic and Gulf coasts of the continental United States the continental shelf is generally about 50 to 100 miles wide and terminates at depths ranging from 300 to 900 feet. Within this regime four significant differences in conditions on the shelf are reflected in the estuarine zone:

(1) The Gulf of Maine forms an embayment between Cape Cod and Nova Scotia, and the general configuration of deep basins close to shore with broad banks seaward of them is unique to this part of the coast (Figure IV.1.3). While the shoal waters on the shelf serve to protect the New England coast from the full force of the ocean swells, the deep embayment near shore and the narrow trough which connects it to the ocean cause the great tide ranges and strong currents characteristic of the region. These currents tend to reduce deposition of sediments close inshore, particularly along the Maine coast where the tide range is greatest and the currents strongest.

(2) Cape Hatteras is a region where the deposition of sediments on the wide shelf at the meeting place of two major ocean currents has resulted in the building of a series of barrier islands out over the shelf and the formation of a wide shallow embayment (Pamlico Sound) behind them (Figure IV.1.4). This sedimentation process has reduced the width of the continental shelf to less than 20 miles at this point and created the infamous Diamond Shoals seaward of the barrier islands.

(3) South Florida, from Miami to beyond the Florida Keys, has virtually no continental shelf; this is probably related to the passage of the Gulf Stream through the narrow channel between the Bahama Islands, Cuba, and Florida (Figure IV.1.5). These same islands, however, serve to protect the southern part of Florida from heavy ocean swells, while the steady current keeps sediments from depositing on the offshore coral formations of the Florida Keys and tends to spread coral growth northward along the Florida coast.

(4) The Mississippi River, draining about 41 percent of the continental United States, has built a delta entirely across the continental shelf and now deposits most of its sediments on the slope beyond (Figure IV.1.6). The generally enclosed nature of the embayment forming the Gulf of Mexico has permitted the formation of this delta

and its associated channels and marshlands, as well as the combination of barrier island and coastal marshland formation which makes up the majority of the Gulf of Mexico estuarine systems.

On the Pacific coast of the continental United States, the continental shelf is 2 to 20 miles wide and terminates at depths of 300 to 600 feet. Pouring over this narrow, steep shelf is the full force of the Pacific Ocean swell; this makes for excellent surfing, but it also leads to considerable erosion of the shoreline. Shoreline erosion by wave action with the development of a beach and bluff configuration is typical of this part of the coastline (Figure IV. 1.2). Strong currents and turbulent waters near the shore tend to remove eroded material rapidly, and extensive shoal areas rarely occur.

The continental shelf along all the coasts of Alaska is wide; in the Bering Sea it averages 400 miles. The Bering Sea shelf is the flattest area of this size on the face of the earth, primarily because of the fine silt deposited on an irregular rocky platform by glacier-fed rivers.

OCEAN CURRENTS

The major ocean currents impinging on or passing close to the continent exert strong, if subtle, effects on the estuarine zone;

see Figure IV.1.1.

The best known of these is the Gulf Stream which moves northward along the South Atlantic coast from Florida to Cape Hatteras, where it turns east out across the Atlantic. Between Cape Hatteras and Newfoundland, water from the Labrador Current moves slowly southward between the Gulf Stream and the coast.

The Labrador Current, a cold water mass with abundant plant nutrients, makes the Grand Banks off Newfoundland one of the most productive fisheries of the world. While much of the Labrador Current mixes with the Gulf Stream, some of its water enters the Gulf of Maine as part of the strong tidal and wave-driven flow, and still more drifts down the Middle Atlantic coast from Massachusetts to North Carolina.

The Gulf Stream is very warm water from subtropical latitudes, and carries with it subtropical life forms as well as heat. Its warming effect on the land can be seen in the difference in vegetation above and below Cape Hatteras, as well as in differences in kinds of aquatic life (Figure IV.1.7).

A major part of the Gulf Stream emerges from the warm, subtropical Gulf of Mexico and flows around the tip of Florida. These waters nurture the great shrimp fishery and warm the coasts of northern Europe as well as those of the southeastern United States.

Along the west coast of North America the eastward-flowing warm current of the Pacific Ocean (the North Pacific Current) splits at about the latitude of the United States-Canadian border; the portion moving south is called the California Current, while that moving north into the Gulf of Alaska is called the Alaska Current.

The California Current exerts a moderating effect on contiental temperatures as it moves southward; the major effect, however, occurs during the spring and early summer when the winds are such that in some places the California Current moves away from the coast and cold, nutrient-laden deep water comes to the surface near the shore. Two major zones of this "upwelling" are off Santa Barbara and off Cape Mendocino, near the northern part of California. During other seasons a complex series of eddies and countercurrents develops, all of which tends to make the nearshore areas very productive.

The Alaska Current exerts a warming effect on the southern part of Alaska, similar to that of the Gulf Stream in northern Europe. The Bering Sea, which receives some water from the Pacific Subarctic Current, is the birthplace of the cold deep currents of the Northern Pacific, and the waters within the Bering Sea are very cold and rich in nutrients.

None of the effects of continental shelf and ocean current structure are clearly visible and dramatic. They are a matter of slight differences in degrees of temperature, of concentrations of certain

chemical compounds, or of speed of motion. Yet they help to explain why lobsters grow in Maine and not along the coast of South Carolina, and they form one basis for regarding the national estuarine system as a unified whole, not as a group of unique coastal systems.

STRUCTURE OF THE COASTLINE

The configuration of the coastline itself, even though subject to additional molding by the flow of rivers to the sea, is closely related to the shape and structure of the continental shelf. A wide continental shelf is generally associated with lowland next to the coast, while a narrow shelf is associated with mountainous terrain. These associations throughout the estuarine zone of the United States have produced estuarine systems characteristic of particular regions.

The northern part of the North American continent was once covered by an ice sheet of continental dimensions, which left its impress on the estuarine zone as far south as New York City on the Atlantic coast and Puget Sound on the Pacific coast. These massive glacial rivers, sometimes over one mile thick, cut their way to the ocean, terminating somewhere in the vicinity of the edge of the continental shelf on both coasts (Figure IV.1.8).

The result of their passage is the sharply sculptured and generally steep shoreline associated with the New England, Puget Sound, and Southeast Alaska regions. The submarine topography of these regions

is similar to that above the water, except where earth and rock have eroded from the land above the water and been deposited on the land under the water. The estuarine zone along formerly glaciated coasts is a region of deep, heavily indented embayments, many islands, steep rocky shores, predominantly evergreen forests reaching nearly to the water, irregular bottom topography, and vistas of great scenic beauty (Figure IV.1.9).

The unglaciated parts of the Atlantic coast and of the Gulf coast consist of relatively flat terrain in which coastal embayments and marshes are the predominant estuarine features. These are coasts formed primarily of sediments eroded from ancient mountains, and along which the embayments and marshes form traps for sediments the rivers bring down to the sea.

The estuarine zones along these coasts may be of many forms, but the general impression is one of great expanses of shallow water and aquatic vegetation, extensive sand dunes and sandy ocean beachfront, and narrow and carefully maintained navigation channels with port facilities well inland (Figure IV.1.10).

The Pacific coast of the conterminous United States is actively being eroded by wave action against the exposed shoreline. The major coastal feature is narrow beach or rocks at the base of steep bluffs. Deep embayments behind headlands or shallow indentations in the coast

are typical of the estuarine zone.

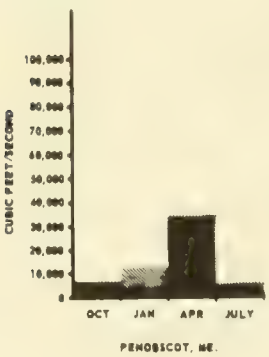
The southern coast of Alaska is the only part of the United States with glaciers existing in the estuarine zone. Glacier-fed estuaries have much floating ice, usually in the form of small icebergs, and very steep sides. The water is icy cold and often milky with sediment from earth and rock ground to a fine flour by the movement of the ice across the land (Figure IV.1.11).

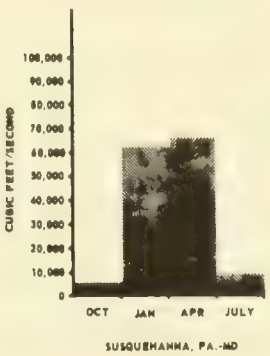
RIVER FLOW

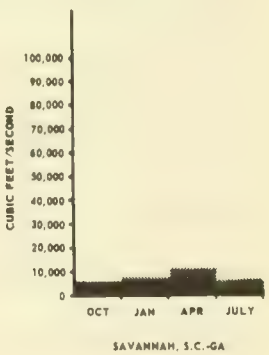
The estuarine zone is also shaped through erosion and sediment transport by fresh water making its way to the sea. Along the coastlines of the continental shelf of the United States are streams and rivers carrying water from land runoff to the sea. These waterways range from the Mississippi River down to the tiniest stream trickling across the sands of a beach.

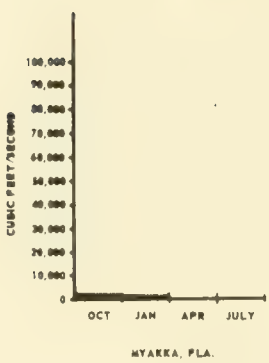
Figure IV.1.12 illustrates typical seasonal variation in river flow into the estuarine zones of the United States. Everywhere there is a pronounced annual cycle: peaking sharply in the spring in Alaska and New England, peaking from early summer to early fall along the Atlantic and Gulf coasts, and reaching a maximum in late winter along the Pacific coast.

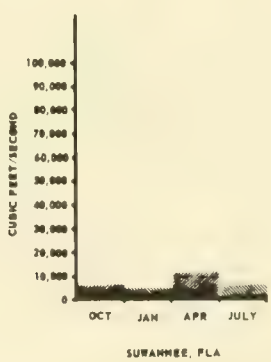
FIGURE IV.1.12 EXAMPLES OF VARIATION IN RIVER FLOW











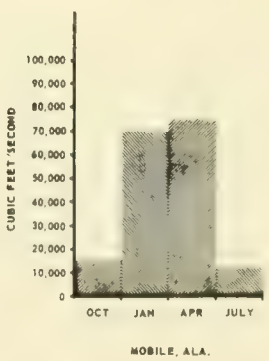
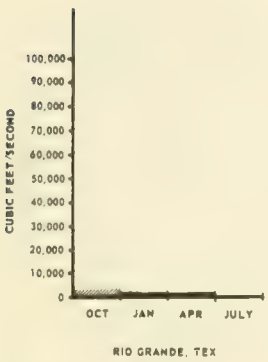


FIGURE IV.1.12 EXAMPLES OF VARIATION IN RIVER FLOW (continued)



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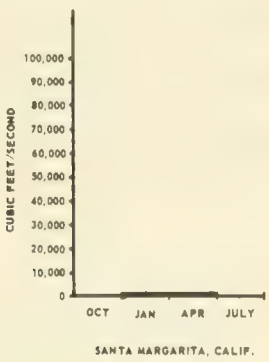

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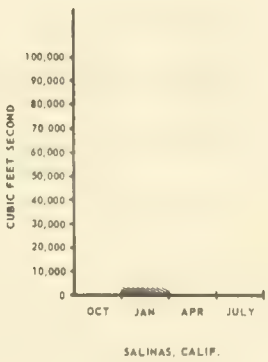

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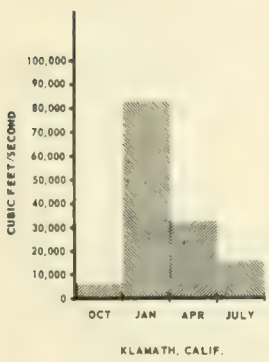

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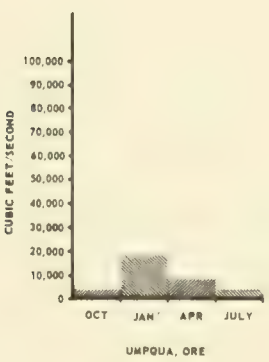

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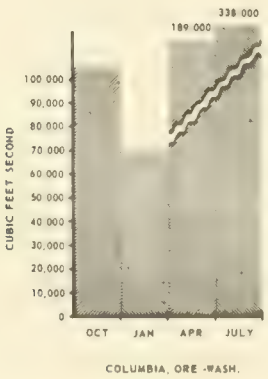
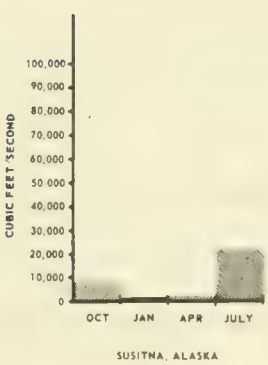
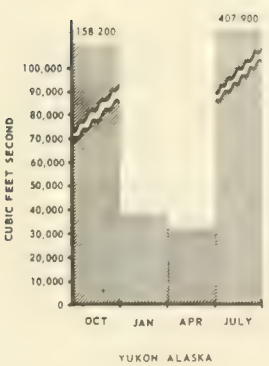


COLUMBIA, ORE.-WASH.



SUSITNA, ALASKA



YUKON, ALASKA

Annual cycles of river flow depend on the annual variation of temperature as well as of precipitation, and the total volumes of water and sediment moved reflect not only the total amount of precipitation, but also the sizes and slopes of drainage basins and the types of soil over which the rivers flow in their fall to the sea.

All river flows begin as either rain, snow, or ice. While rain moves almost immediately into the hydrologic system as ground water and as surface runoff, snow and ice may remain for several months on the ground until they melt under the warmer temperatures of spring. This sudden influx of several months' precipitation into the hydrologic system frequently results in severe erosion and flooding with heavy transport of sediment into the estuarine zone.

River basin drainages unaffected by winter freeze-up conditions, such as most of those on the Southeast Atlantic and Gulf coasts, also erode and carry sediment loads, but their effects are distributed more equally around the year. Coasts with low-lying drainage basins tend to have marshes which trap sediments, reducing erosion in coastal areas.

Table IV.1.1. shows the magnitude and distribution of river flows entering the estuarine zone of the United States. Two river systems, those of the Mississippi and the Columbia, drain 62 percent of the land area of the conterminous United States and account for 50 percent of the land runoff passing through the estuarine zone. The

TABLE IV.1.1 RIVER FLOW IN THE ESTUARINE ZONE OF THE UNITED STATES

BIOPHYSICAL REGION	DRAINAGE AREA (SQ. MI)	TOT. FRESHWATER RUNOFF (CUBIC FEET/SEC)	DRAINAGE AREA PER/MILE OF OCEAN COASTLINE	RUNOFF PER MILE OF TOTAL TIDAL SHORELINE	MAJOR RIVER BASINS (NR)	TOTAL GAGED DRAINAGE AREA (SQ. MI)	>1000 SQ MI DRAINAGE AVERAGE ANNUAL RUN OFF (CUBIC FT/SEC)
NORTH ATLANTIC	40,700	72,000	30	16	5	18,600	30,900
MIDDLE ATLANTIC	69,700	106,000	54	15	6	35,300	51,400
CHESAPEAKE	64,500	79,800		15	6	47,100	55,500
SOUTH ATLANTIC	149,500	154,000	182	16	12	68,600	70,200
CARIBBEAN	10,400	11,500	7	3	0	?	0
GULF (TOTAL)	1,704,000	799,000	750	52	21	1,394,000	700,000
EXCLUDING MISS.	464,000	249,000	274	19	20	249,000	155,000
SOUTHWEST PACIFIC	94,300	83,400	79	27	8	49,000	30,500
NORTHWEST PACIFIC	314,000	368,000	469	77	9	275,000	293,000
EXCL. COLUMBIA	56,000	133,000	84	28	8	38,000	98,000
ALASKA (TOTAL)	700,000	NOT AVAILABLE	47		16	345,000	351,000
EXCL. YUKON	340,000	NOT AVAILABLE	22		15	86,000	175,000
PACIFIC ISLANDS	6,710	NOT AVAILABLE	6		0	?	0
TOTALS (INCLUDING ALASKA AND PACIFIC ISLANDS)	3,116,800	2,000,000	124		83	2,232,600	1,588,500
TOTALS (EXCLUDING ALASKA AND PACIFIC ISLANDS)	2,410,100	1,568,700	264	29	67	1,978,600	1,237,600
TOTALS (EXCLUDING ALASKA, PACIFIC ISLANDS, MISS.R, & COLUMBIA R.)	912,000	794,000	106	18	65	595,000	492,500

REFERENCE: THE NATIONAL ESTUARINE INVENTORY
DATA SOURCES: U.S. GEOLOGICAL SURVEY, U.S. COAST AND GEODETIC SURVEY

Yukon has a drainage area of about 360,000 square miles in Alaska and Canada, about one-third that of the Mississippi, and ranks between the Mississippi and Columbia as one of the three major river systems of the Nation.

The mouths of these three rivers form estuarine systems unique in the estuarine zone of the United States. The tremendous volumes of water discharged* by each of these is the dominating environmental factor where the river enters the sea.

The Mississippi and Yukon reach the ocean after passing through many hundreds of miles of low-lying, easily erodable land. Immense deltas formed at the mouth of each river as the great volumes of suspended material accumulated in this passage were deposited at the place where the river currents were slowed down by the sea (Figure IV.1.12A and Figure IV.1.6). The Columbia collects relatively little sediment in its passage over rocky terrain, and is confined near its mouth to a narrow channel where it has cut its way to the ocean through coastal mountain ranges. The deposited sediments form only an offshore bar which is continually cut away and re-established by the ocean swells and currents sweeping in over the narrow continental shelf (Figure IV.1.12B).

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*In a little over an hour on an average day, the Mississippi discharges into the Gulf of Mexico enough water to supply the domestic water needs of the entire present population of the United States.

There are 80 other river basins in the United States having drainage areas of over 1000 square miles; these, with the three river systems already mentioned, account for land runoff from 85 percent of the entire land area draining to the estuarine zone. Over half of these are in the Gulf, Alaskan, and South Atlantic biophysical regions. There are none in the Caribbean and Pacific Islands regions.

The ratio of drainage basin size to miles of ocean coastline in each Region, as shown in Table IV.1.1, is an index of the relative importance of upland runoff conditions to the estuarine zone. In the North Atlantic biophysical region, for example, runoff comes on the average only from a distance of 30 miles inland. In the South Atlantic region, however, runoff comes from an average distance of 182 miles, thus indicating that large river basins are far more important to the estuarine zone in the South Atlantic region than in the North Atlantic.

The ratio of runoff to total miles of tidal shoreline is an index of the importance of land runoff in estuarine stratification and water movement patterns. A low ratio means there is little runoff in proportion to the size of the estuarine zone, as in the Caribbean region, and water stratification generally is not significant in this region; while high ratios, as in the two Pacific regions, indicate high proportionate land runoff and stratification-dominated estuaries.

Regional averages like those in Table IV.1.1 are important in that they show that there are general unifying criteria through which lessons learned in one part of the national estuarine system can be applied to other parts of the estuarine zone.

SEDIMENTATION

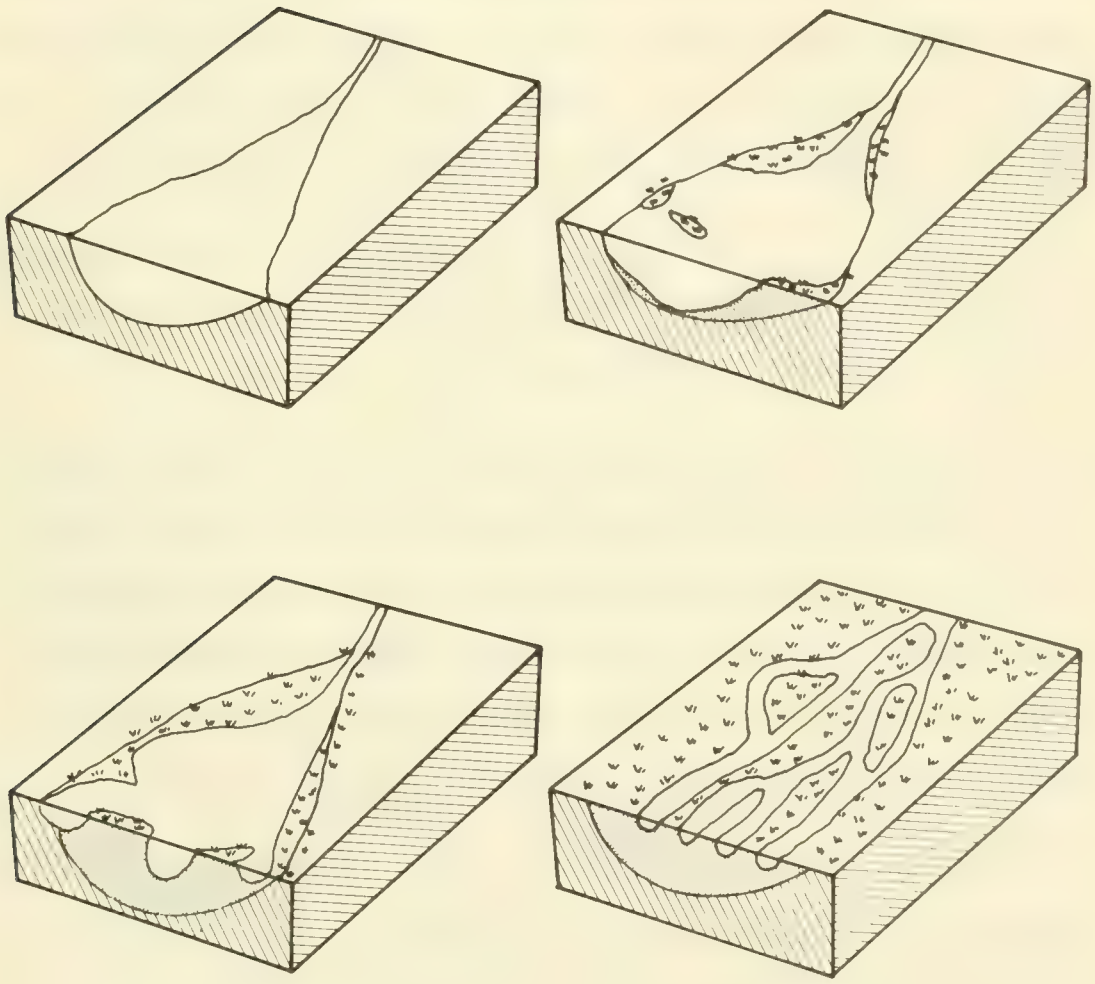
The general outlines of the estuaries, lagoons, and embayments in the estuarine zone of the United States were formed by erosion from land runoff during the last ice age when sea levels were much lower than they are now. As the sea level rose, the drowned river mouths became zones of mixing, sediment deposition, and erosion where the rivers and tidal currents met. These erosion and sedimentation processes molded the estuarine zone into its present shape and continue to change it.

The greatest changes occurred in those regions where the surface soils and clays on wide, gently sloping coastal plains rapidly eroded from the land and came to rest in the estuarine zone or farther out on the continental shelf. Least change occurred where coastal plains and continental shelves are narrow or consist mostly of resistant rock.

Figure IV.1.13 illustrates the evolution of an estuary from a drowned river valley to a coastal marsh. The estuarine zone of the United States from New York to Texas abounds with examples of this evolutionary process (Figure IV.1.14). Delaware Bay has not yet

Figure IV.1.13

STAGES IN ESTUARINE SYSTEM MODIFICATION
DUE TO SEDIMENTATION



been cut off from the sea by barrier islands, Mobile Bay illustrates the initial formation of offshore bars, Matagorda Bay shows the full development of barrier islands, and the marshes around the mouth of the Satilla River represent the ultimate stage in the filling of an estuary.

The great ice sheet which once covered the estuarine zones of New England, northwest Washington, and southeast Alaska scoured off much of the readily erodable surface material in the coastal watersheds, thus, natural sedimentation has been a relatively minor factor in modifying estuaries in these areas. Narragansett Bay and Puget Sound, among many others, still maintain the great depths typical of glacially formed embayments.

Near the edge of the ice sheet, however, where the scoured-off earth and rock carried along under and in the ice finally stopped as the glaciers met the sea and melted, small, shallow bays formed in the glacial debris and subsequently developed offshore sand spits and barrier islands as illustrated by Moriches Bay (Figure IV.1.15) on the south side of Long Island, which is formed of such glacial debris.

Abundant sediment eroded from the coastal ranges along the Pacific coast of the continental United States has nearly filled several estuaries, and wide tidal flats are common in the few estuaries along these coasts (Figure IV.1.16). The Columbia, however,

collects a proportionately less suspended load of sediment as it comes down through the less-erodable volcanic mountains and plateaus of the Pacific Northwest.

The southern part of the Florida peninsula is far from the sources of coastal plain sediment which has filled estuaries immediately to the north. Locally derived sediments, combined with the results of plant and animal activity, are the great estuarine modifiers in this region. Mangrove swamps on the Southwest coast and coral reefs on the Southeast (Figure IV.1.17) are typical coastal formations.

Table IV.1.2 gives estimated total quantities of suspended sediments entering the estuarine zone and shows the kinds of sediments typical of each region. The data leading to this table include the effects of human activity as well as natural sedimentation. The most significant thing about this table is the paucity of data leading to these estimates. The sediments carried by only 26 of the rivers entering the estuarine zone have been measured sufficiently well to permit even these estimates (IV-1-2).

The great volume of sediments carried by the Mississippi, as contrasted to the quantity carried by the Columbia, illustrates one of the major differences between a river forming a delta and one not forming a delta. The contrast between the sediment loads being carried by the rivers of the Middle Atlantic and Chesapeake regions and those of the South Atlantic and Gulf also illustrate why the

TABLE IV.1.2 CHARACTERISTICS OF SEDIMENT LOADS ENTERING AND SEDIMENTS RESIDENT IN THE ESTUARINE ZONE

BIOPHYSICAL REGION	AVERAGE ANNUAL SUSPENDED SEDIMENT LOAD (TONS/SQ MI)	(TONS)	NUMBER OF RIVERS SAMPLED	KINDS OF SEDIMENTS IN THE ESTUARINE ZONE
NORTH ATLANTIC	NOT AVAILABLE	NOT AVAILABLE	0	GLACIAL DEBRIS- LITTLE INPUT FROM RIVERS CLAY SILT IN DEEP AREAS; SAND GRAVEL AROUND EDGES.
MIDDLE ATLANTIC	220	15,300,000	5	SILT, CLAY IN DEEP AREAS; FINE SAND ELSEWHERE
CHESAPEAKE BAY	130	8,640,000	3	SILT, CLAY IN DEEP AREAS; FINE SAND ELSEWHERE
SOUTH ATLANTIC	389	58,100,000	1	FINE SAND PREDOMINATES; ORGANIC SILT IN RIVERS AND SWAMPS
CARIBBEAN	NOT AVAILABLE	NOT AVAILABLE	0	FINE SAND, EXCEPT FOR CORAL REEFS AND MANGROVES
GULF				
(1)EXCL. MISS.	124	57,600,000	7	(1)SILTS AND CLAYS WITH SANDS ABUNDANT AROUND MARGINS ONLY
(2)MISSISSIPPI	244	305,000,000	1	(2)FINE SILTS AND CLAYS, COVERED BY FINE SAND WHERE DELTA-MAKING IS INACTIVE
PACIFIC SOUTHWEST				
PACIFIC SLOPES	398	21,000,000	2	FINE SAND IN CHANNELS, SILTS AND CLAYS
CENTRAL VALLEY	71.4	3,000,000	2	AROUND EDGES AND ON TIDAL FLATS
PACIFIC NORTHWEST				
PACIFIC SLOPES	361C	98,000,000	3	FINE SAND IN CHANNELS, SILTS AND CLAYS
COLUMBIA	112	29,000,000	2	AROUND EDGES AND ON TIDAL FLATS
ALASKA	NOT AVAILABLE	NOT AVAILABLE	0	MIXTURE OF GRAVEL, SILT AND GENERAL GLACIAL DEBRIS ON SOUTHEAST, SOUTH. EXTREMELY FINE 'FLOUR' ON SOME PARTS OF SOUTH AND SOUTHWEST.
PACIFIC ISLANDS	NOT AVAILABLE	NOT AVAILABLE	0	SAND, CORAL, SLIGHT AMOUNTS OF SILT NEAR RIVERS

REFERENCE: THE NATIONAL ESTUARINE INVENTORY

DATA SOURCES: U.S. GEOLOGICAL SURVEY

evolution of drowned river valleys has progressed farther in the latter regions.

The two Pacific Coast regions are striking in that rivers with drainage only from the coastal mountain ranges carry much greater sediment loads than those which drain the interior ranges.

CLIMATE

Solar energy striking the earth sets up complex cycles of water and energy flow from the oceans to the sky and the land and back again. That part of the energy cycle occurring in the atmosphere gives rise to the various combinations of weather phenomena which make up local climates. Land, sea, and sky are mutually dependent in producing specific climates, and the great ocean currents play their indirect roles in modifying the climates of the estuarine zone in addition to their direct effects discussed earlier.

The annual distributions of temperature, precipitation, sunlight, and prevailing winds as well as the total amounts of each are of the greatest significance. Table IV.1.3 and Figure IV.1.18 summarize the major climate characteristics in the estuarine zone of the United States.

Precipitation may fall as rain, snow, or other forms of ice, depending on temperature; the form of precipitation has not only local impact, but also affects annual patterns of river flow in

TABLE IV.1.3 CLIMATOLOGICAL CHARACTERISTICS

BIOPHYSICAL REGION	MEAN TEMPERATURES (DEG. F)					PRECIP.(IN)		HUM. %		PREVAILING WIND (KNOTS, DIRECTION)				SOLAR RADIATION HRS PER DAY /% OF POSSIBLE			
	ANNUAL	JAN.	APR.	JULY	OCT.	NORM TOTAL	SNOW, SLEET NORM TOTAL	AM	PM	JAN.	APR.	JULY	OCT.	JAN.	APR.	JULY	OCT.
NORTH ATLANTIC																	
PORTLAND,ME.	46.0	21.8	42.5	68.1	48.6	42.9	71.7	81	60	8N	9S	7S	8N	9.3/54	13.4/56	15.1/67	11.1/5
MIDDLE ATLANTIC																	
NANTUCKET,MASS.	49.1	32.5	43.8	67.5	53.8	43.7	33.9	82	71	13NW	13SW	10SW	11SW	9.5/40	13.3/55	14.9/63	11.1/5
NEW YORK,N.Y.	54.5	33.2	51.4	76.8	58.3	42.4	29.7	72	57	10NW	NW	7SW	8SW	.6/50	13.3/5	14.8/65	11.1/5
C. HATTERAS,N.C.	62.2	46.6	59.3	78.0	65.4	54.5	2.9	82	67	10NE	12SW	9SW	10NE	10.0/62	13.1/67	14.3/70	11.3/7
CHESAPEAKE BAY																	
BALTIMORE,MD.	57.6	37.3	55.7	79.1	60.0	44.2	22.7	71	54	9SW	10SW	8SW	8SW	9.7/48	13.2/59	14.7/65	11.2/5
SOUTH ATLANTIC																	
CHARLESTON,S.C.	65.0	50.3	64.3	80.1	66.2	49.2	0.1	87	56	8SW	9SW	7SW	7NE	10.2/62	13.0/75	14.1/69	11.4/7
JACKSONVILLE,FLA	69.5	55.9	68.7	82.6	71.0	53.4	0.1	87	54	7NW	8SE	7SW	8NE	10.4/57	12.9/70	13.9/59	11.5/5
MIAMI,FLA	75.1	66.9	74.2	81.8	77.8	46.3	0.0	85	60	8NW	9SE	7SE	8NE	10.7/68	12.8/72	13.6/62	11.5/5
CARRIBEAN																	
KEY WEST,FLA	76.8	69.6	75.8	83.3	79.0	40.0	0.0	80	67	11NE	11SE	9SE	10NE	71	80	69	5
SAN JUAN,P.R.	78.0	74.4	76.6	80.4	80.0	64.2	0.0	83	66	7NE	8NE	8NE	6NE	11.1/66	12.6/65	13.1/64	11.7/6
GULF																	
TAMPA,FLA	72.2	61.2	71.4	81.6	74.7	51.6	TRACE	88	57	8N	9NE	7E	8NE	10.6/57	12.8/72	13.8/60	11.5/5
PORT ARTHUR,TEX.	68.5	53.6	68.2	81.9	70.3	53.1	0.6	91	62	10N	11S	7S	8N	10.5/44	12.9/51	13.9/65	11.5/5
BROWNSVILLE,TEX.	73.7	61.4	73.9	84.0	75.9	26.8	TRACE	90	61	10SE	13SE	10SE	9SE	10.7/47	12.8/54	13.6/81	11.5/5
PACIFIC SOUTHWEST																	
SAN DIEGO,CAL.	62.4	54.9	60.5	69.3	65.0	10.9	TRACE	61	61	5NE	6NW	6NW	5NW	10.2/58	13.0/61	14.1/67	11.4/6
S.FRANCISCO,CAL.	55.6	47.9	54.1	60.4	59.4	17.4	TRACE	71	67	6NW	10NW	12NW	8NW	9.9	13.2	14.5	11.3
PACIFIC NORTHWEST																	
ASTORIA,ORE.	51.4	40.1	49.7	60.8	54.1	76.0	3.7	78	73	7E	7NW	7NW	6SE	9.0	13.5	15.4	11.3
SEATTLE,WASH.	53.2	40.7	51.8	65.6	54.4	31.9	8.4	72	60	7S	7S	6NW	6SE	8.9/28	13.6/47	15.6/63	10.9/3
PACIFIC ISLANDS																	
HONOLULU,H.I.	75.2	72.0	73.3	77.9	77.5	23.9	0.0	73	58	9NE	11NE	12NE	10NE	11.0/56	12.6/73	13.3/77	11.7/7
ALASKA																	
JUNEAU,A.	40.6	26.2	39.5	54.7	41.9	56.9	90.5	72	82	7N	8SE	7N	8SE	7.1/29	14.4/37	17.6/27	10.3/1
ANCHORAGE,A	35.3	13.0	35.4	57.3	36.0	14.3	80.4	70	62	5NE	6N	6S	5N	6.4/38	14.7/58	18.5/42	10.1/4
NOME,A.	26.3	5.6	21.0	49.6	30.3	18.7	60.5	81	77	10E	9E	9SW	10N	42	52	60	3
BARROW,A.	10.1	-15.1	20.2	39.7	17.1	4.1	27.0	79	77	10SE	10NE	10E	12E	0.0	16.5	24.0	8.3

REFERENCE: THE NATIONAL ESTUARINE INVENTORY

DATA SOURCE: U.S. WEATHER BUREAU

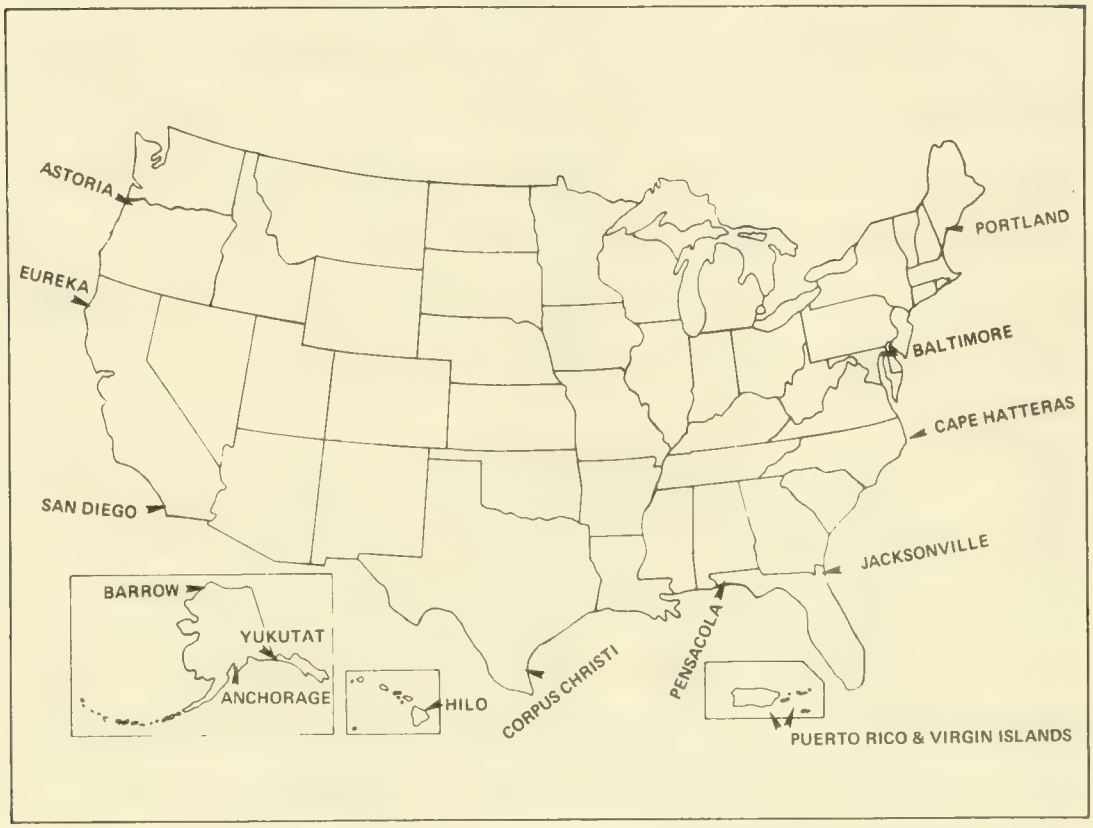
rivers draining to the coast. There is a tendency for precipitation along the northern Atlantic coast to be heaviest during the cooler months and for much of it to fall as snow; the Pacific coast, except for Alaska, has a similar precipitation pattern with much less snowfall. The southern Atlantic, Gulf, and Alaskan coasts receive their heaviest precipitation in the summer and fall, as do Puerto Rico and the Virgin Islands.

Local air, water, and ground temperatures, which govern the form in which precipitation occurs, are primarily a matter of solar radiation, which becomes more intense in latitudes nearer the equator. Local temperatures are, however, greatly moderated by local precipitation, cloud cover, nearby ocean conditions, and prevailing winds. Two examples serve to illustrate this point:

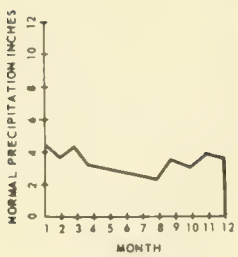
(1) Key West, Fla., on an island in the warm waters of the Gulf of Mexico, has an average temperature of 77°F.; Brownsville, Tex., in about the same latitude but on the mainland, has an average temperature of 74°F. At Key West annual temperatures, moderated by the marine environment, range over only 49 degrees, whereas the range at Brownsville is 85 degrees.

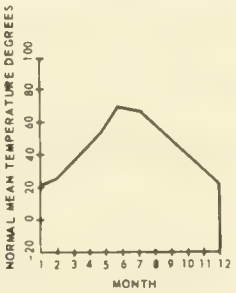
(2) Astoria, Oreg., at the mouth of the Columbia River, and Portland, Me., are both in the same latitude in zones of prevailing westerly winds. At

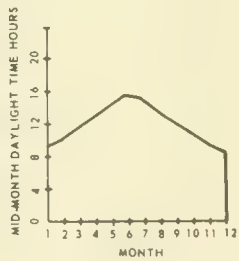
FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE



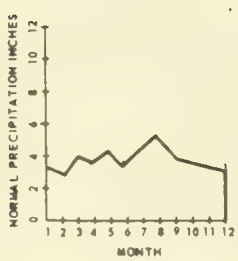
Portland, Maine

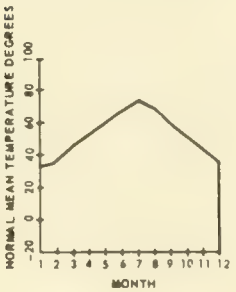






Baltimore, Maryland





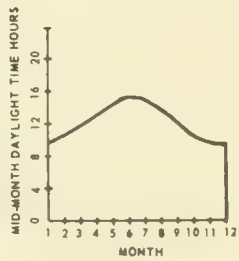
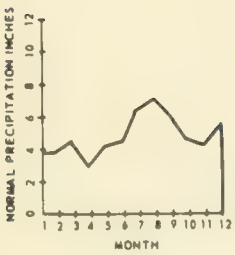
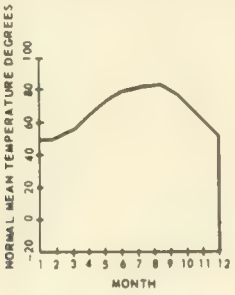
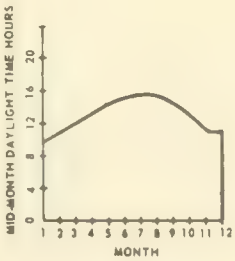


FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE (continued)

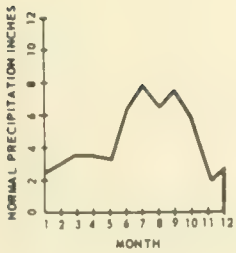
Cape Hatteras, North Carolina

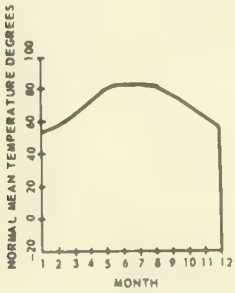


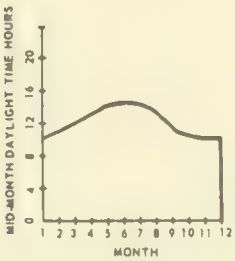




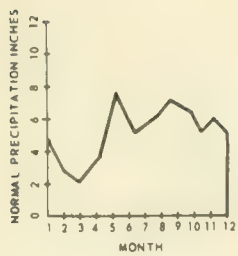
Jacksonville, Florida

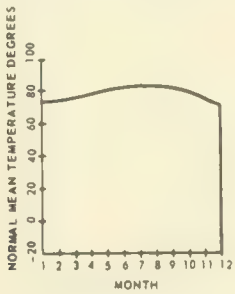


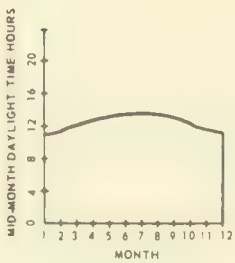




Puerto Rico & Virgin Islands







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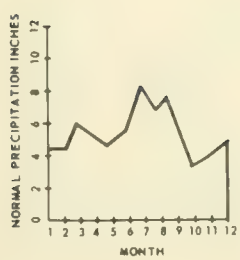

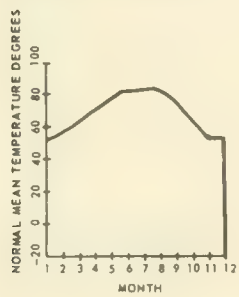

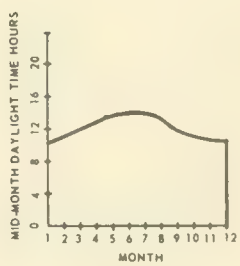

FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE (continued)

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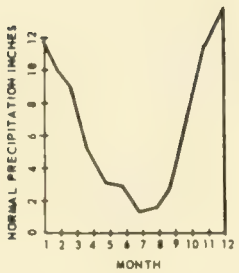
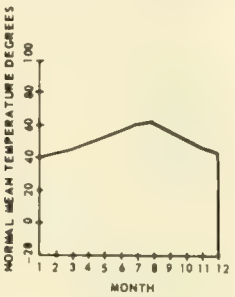
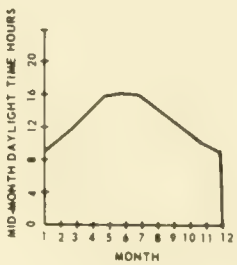
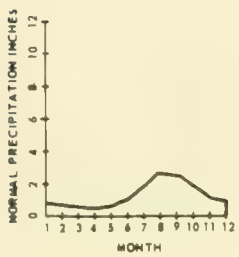
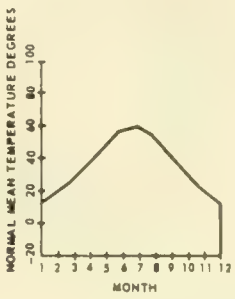


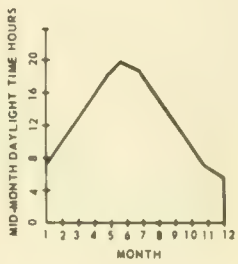




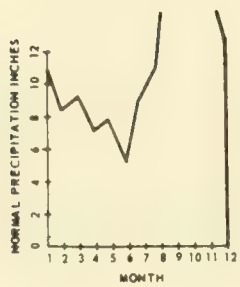
Anchorage, Alaska

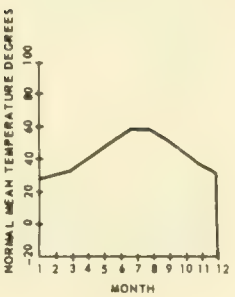


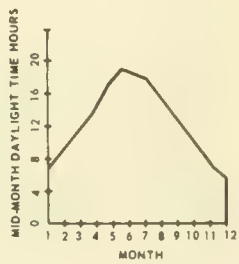




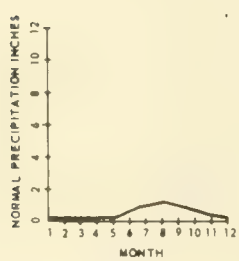
Yukutat, Alaska

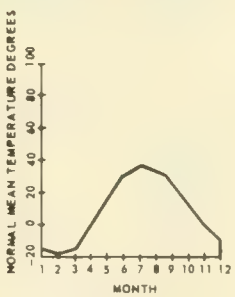






Barrow, Alaska





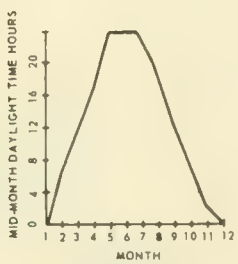


FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE (continued)

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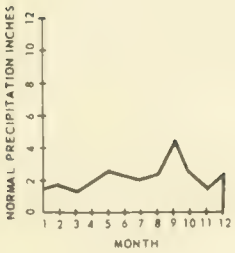
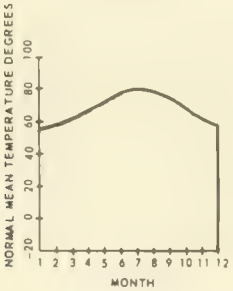
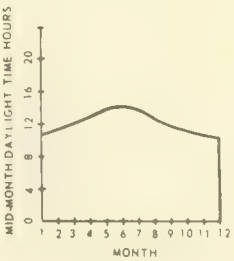
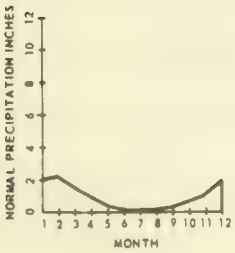
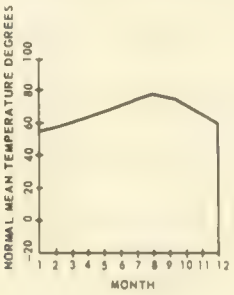


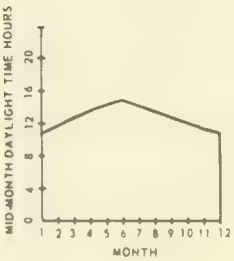




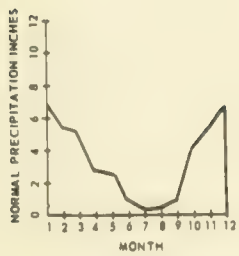
San Diego, California

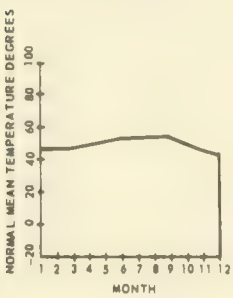


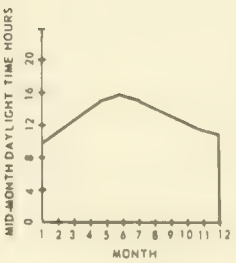




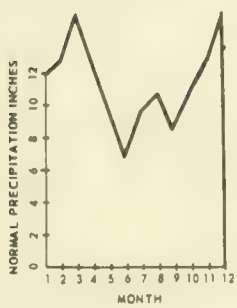
Eureka, California

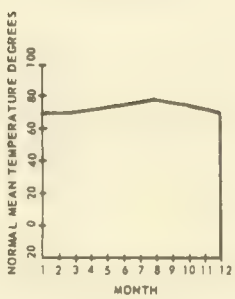


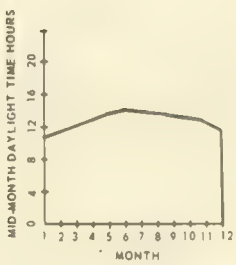




Hilo, Hawaii







Astoria, where the winds are blowing off the Pacific Ocean, there are 76 inches of precipitation, including 4 inches of snow. At Portland the prevailing winds blow off the continental land mass and there are 43 inches of precipitation, but 72 inches of snow.

TIDE

The tide stands alone as a controlling force in the estuarine environment. The ebb and flow of the tide are the great facts of the estuarine zone, and have determined much of man's history from the time Julius Caesar lost a fleet because of the tides in the English channel to the time of D-Day in 1944, which was set because of the right combination of tide and moon.

Tides are easily understood. The sun, the moon, and the earth mutually attract each other, according to Newton's law of gravitation*; the great masses of fluid in the ocean, being more sensitive to tiny changes in gravitation force than the solid land, are pulled about rather freely in a predictable fashion based on the relative positions of sun, moon, and earth. They are predictable to such an extent that tables of accurate predictions of tidal height are

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*It is interesting to note that observations of the rhythmic rise and fall of the tide led to the mathematical concepts through which the law was formulated.

published for each day of each year for each major port of the world. Such predictions are valuable both to the captain trying to dock a large oil tanker and to the fisherman who is trying to find where the big ones are biting.

Perhaps because tides are so easily understood and predicted, and are so easily observable everywhere, their importance in the estuarine zone has been largely overlooked.

Table IV.1.4 gives typical tidal characteristics in several estuaries of the United States. It is immediately apparent that tides on each coast of the United States are different. Along the Atlantic and Pacific coasts there are semidiurnal tides, i.e., two complete tides in a little over one day, but the Atlantic tides are equal and the Pacific tides are unequal. In the Gulf of Mexico most places have one tide a day, i.e., diurnal, but some places such as Tampa Bay exhibit both kinds of tides at different times of the month.

Tide ranges, i.e., the difference between high water and low water, are not so uniform. These are largely a matter of shape, size, and bottom material in individual estuarine areas. Ranges vary from the barely noticeable rises and falls of some lagoons along the Gulf of Mexico to the tremendous 28-foot range in Alaska's Cook Inlet.*

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*A tidal bore, a single breaking wave bringing in the flood tide, is characteristic of Turnagain Arm of Cook Inlet at certain times. This is the only tidal bore in the United States.

TABLE IV.1.4 TYPICAL TIDAL CHARACTERISTICS OF THE ESTUARINE ZONE OF THE UNITED STATES

BIOPHYSICAL REGION	TYPE OF TIDE	TIDAL RANGE (FT) MEAN	SPRING	DIURNAL*	MAX. TIDAL CURRENT VELOCITY FLOOD	EBB
NORTH ATLANTIC						
EASTPORT, ME. (BAY OF FUNDY)	EQUAL SEMIDIURNAL	18.2	20.7		3.5	3.5
ISLE DE HAUT, ME (PENOBSCOT R.)	EQUAL SEMIDIURNAL	9.3	10.7		1.6	1.7
PORTSMOUTH HARBOR, N.H.	EQUAL SEMIDIURNAL	8.7	10.0		1.4	2.1
BOSTON HARBOR, MASS.	EQUAL SEMIDIURNAL	9.5	11.0		2.0	1.5
MIDDLE ATLANTIC						
DUMPLING ROCKS (BUZZARDS BAY)	EQUAL SEMIDIURNAL	3.7	4.6		0.9	1.3
THE NARROWS (N.Y. HARBOR)	EQUAL SEMIDIURNAL	4.5	5.5		2.0	2.3
CAPE MAY HARBOR, N.J.	EQUAL SEMIDIURNAL	4.4	5.3		2.1	2.5
VIRGINIA BEACH, VA.	EQUAL SEMIDIURNAL	3.4	4.1		1.3	0.9
CHESAPEAKE BAY						
WOLF TRAP LIGHT (LOWER BAY)	EQUAL SEMIDIURNAL	1.0	1.2		1.8	2.2
POINT NO POINT (MID-BAY)	EQUAL SEMIDIURNAL	1.3	1.5		0.5	0.7
CHESAPEAKE BAY BRIDGE, MD.	EQUAL SEMIDIURNAL	0.9	0.9		0.8	1.0
WASHINGTON, D.C. (POTOMAC R.)	EQUAL SEMIDIURNAL	2.1	3.3		0.7	0.3
SOUTH ATLANTIC						
WILMINGTON, N.C. (CAPE FEAR R.)	EQUAL SEMIDIURNAL	3.6	3.9		2.0	1.7
SAVANNAH RIVER ENTRANCE, GA.	EQUAL SEMIDIURNAL	6.9	8.1		1.8	3.0
MAYPORT, FLA. (ST. JOHNS RIVER)	EQUAL SEMIDIURNAL	4.5	5.3		2.5	3.5
FT. PIERCE INLET, FLA.	EQUAL SEMIDIURNAL	2.6	3.0		3.0	3.5
CARIBBEAN						
MIAMI HARBOR, FLA.	EQUAL SEMIDIURNAL	2.5	3.0		2.2	2.4
KEY WEST, FLA.	EQUAL SEMIDIURNAL	1.3	1.5		1.2	2.0
SAN JUAN, P.R.	EQUAL SEMIDIURNAL	1.1	1.3		WEAK & VARIABLE	
CHRISTIANSTED, ST. CROIX	DIURNAL			1.1	WEAK & VARIABLE	
GULF OF MEXICO						
ST. PETERSBURG, FLA. (TAMPA BAY)	DIURNAL			2.3	0.3	0.3
PENSACOLA BAY ENTRANCE, FLA.	DIURNAL			1.1	1.8	2.1
BARATARIA BAY, LA.	DIURNAL			1.1	1.7	1.7
ARANSAS PASS, TEX.	DIURNAL			1.7	1.6	1.9
PACIFIC SOUTHWEST						
SAN DIEGO BAY ENTRANCE, CALIF.	UNEQUAL SEMIDIURNAL	5.7		5.5	1.1	1.4
MONTEREY BAY, CALIF.	UNEQUAL SEMIDIURNAL	3.5		5.5	WEAK & VARIABLE	
SAN FRANCISCO BAY ENT., CALIF.	UNEQUAL SEMIDIURNAL	4.0		5.7	3.1	3.9
POINT ARENA, CALIF.	UNEQUAL SEMIDIURNAL	4.0		5.3	1.3	1.3
PACIFIC NORTHWEST						
HUMBOLDT BAY ENTRANCE, CALIF.	UNEQUAL SEMIDIURNAL	4.5		6.1	1.9	2.3
YAQUINA BAY ENTRANCE, ORE.	UNEQUAL SEMIDIURNAL	5.9		7.3	2.8	2.6
GRAYS HARBOR ENTRANCE, WASH.	UNEQUAL SEMIDIURNAL	6.9		9.0	2.5	2.2
PUGET SOUND (ELLIOTT BAY), WASH	UNEQUAL SEMIDIURNAL	7.5		11.1	WEAK & VARIABLE	
ALASKA						
JUNEAU (GASTINEAU CHANNEL)	UNEQUAL SEMIDIURNAL	13.8		16.6	2.3	2.3
ANCHORAGE (COOK INLET)	UNEQUAL SEMIDIURNAL	25.1		28.1	3.3	3.3
GOODNEWS BAY (KUSKOKWIM BAY)	UNEQUAL SEMIDIURNAL	6.2		8.1	2.6	2.4
POINT BARROW	UNEQUAL SEMIDIURNAL	0.3		0.4	WEAK & VARIABLE	
PACIFIC ISLANDS						
HONOLULU, HAWAII (OAHU)	UNEQUAL SEMIDIURNAL	1.2		1.3	NO DATA	
HILO, HAWAII (HAWAII)	UNEQUAL SEMIDIURNAL	1.6		2.4	NO DATA	
APRA HARBOR, GUAM	UNEQUAL SEMIDIURNAL	NO DATA			1.7	3.4
PAGO PAGO HARBOR, AM. SAMOA	UNEQUAL SEMIDIURNAL	2.5		4.0	NO DATA	

*FOR AN UNEQUAL SEMIDIURNAL TIDE, THE DIURNAL RANGE IS THE EXTREME RANGE OVER THE TWO SEQUENTIAL TIDES IN SLIGHTLY OVER ONE DAY.

REFERENCE: THE NATIONAL ESTUARINE INVENTORY

DATA SOURCE: U.S. COAST AND GEODETIC SURVEY

Even with small tidal ranges and small estuaries, the volumes of water being moved by tidal flow are fantastic. At Charleston, for example, in 6.5 hours 25 billion cubic feet of water move into or out of the harbor in one tidal cycle (IV-1-3). This is more than enough volume of water to supply the entire population of the United States with water for one day. The volume of water flowing into or out of Great South Bay on Long Island in one tidal cycle is adequate in volume to supply the City of New York for one week.

The combination of tidal action and river flow gives rise to that unique phenomenon called an "estuarine circulation pattern", which usually means that fresh water flows in one direction in one layer and salt water flows in the opposite direction in another layer with various degrees of mixing at the interface between them. This type of circulation pattern is of great importance in some of the estuaries along the Atlantic and Gulf coasts, and to a large extent governs the capacity of such estuaries to rid themselves of waste materials.

SECTION 3. THE BIOPHYSICAL ESTUARINE REGIONS

Each estuarine system along the coastline is affected to some extent by all of these dominating environmental factors. In some cases, as in the example already given, the dominance of one particular factor is readily apparent. It is much more often the case that the competing environmental factors are so evenly balanced that none can be said to dominate and the estuarine zone appears to be composed of a bewildering variety of unique systems.

Yet, as an individual person can be identified as a member of the human species by general common characteristics and as a member of particular race by more specific characteristics, so can individual estuarine systems be recognized as belonging to regional and national groupings.

Table IV.1.5 summarizes the dominating environmental factors in the estuarine zone of the United States. Combinations of environmental conditions characteristic of various parts of the coastline permit the grouping of the national estuarine system into ten biophysical estuarine regions of dissimilar Environmental characteristics (Figure IV.1.19).

CHARACTERISTICS OF THE BIOPHYSICAL REGIONS

North Atlantic Estuarine Region: Canadian border to Cape Cod.

TABLE IV 15 DOMINATING ENVIRONMENTAL FACTORS OF THE ESTUARINE ZONE OF THE UNITED STATES

ENVIRONMENTAL FACTOR	NORTH ATLANTIC	MIDDLE ATLANTIC	CHESAPEAKE BAY	SOUTH ATLANTIC	CARIBBEAN	GULF OF MEXICO	PACIFIC SOUTHWEST	PACIFIC NORTHWEST	ALASKA	HAWAII AND ISLAND
CONTINENTAL SHELF WIDTH RANGE (ST. MILES)	150-250	50-100		30-70	3-10 (EXCEPT PTO. RICO)	65-140	2-20 AVERAGE	3-30, WITH EXCEPTIONS OF THE OUTER EDGE	30-150 (VARIES GREATLY IN SE ALASKA)	30-150 (VARIES GREATLY FROM S
BOTTOM TYPE	IRREGULAR, ROCKY	SMOOTHLY SLOPING, LAGOON OFF MAJOR	NOT APPLICABLE	SMOOTHLY SLOPING	VGN. IS.--SMOOTHLY SLOPING (NON-VGN. IF ELA. KEYS)	SMOOTHLY SLOPING	ABOUT 1/3			
OCEAN CURRENTS (2)										
INFLUENCED BY:	LABRADOR CURRENT	LABRADOR CURRENT	NONE	GULF STREAM	GULF STREAM	WATERS FORMING GULF STR.	CALIFORNIA CURRENT	CALIFORNIA-ALEUTIAN CURRENT	ALASKA CURRENT	MID-PA IRCU.
TEMPERATURE (F.)										
MEAN	46	54	59	72	80	73	60	51	42	77
SUMMER	65	73	80	87	87	87	69	56	55	81
WINTER	32	36	39	60	71	54	56	45	30	73
SALINITY (S)										
MEAN	3.03	3.15	1.37	3.55	3.57	3.28	3.36	3.05	3.14	3.
SUMMER	3.1	3.14	1.60	3.62	3.63	3.72	3.34	3.25	3.21	3.
WINTER	3.0	3.13	1.10	3.25	3.49	3.03	3.33	2.95	3.12	3.
COASTLINE STRUCTURE	ROCKY, VERY IRREGULAR, MANY EMBAYMENTS	SMOOTH, MANY LONG EMBAYMENTS	VERY IRREGULAR, EXTENSIVE MARSHES ON EAST SIDE	SMOOTH, LOW LYING, EXTENSIVE MARSHES	INFREQUENT, MANGROVES, CORAL & ROCKS	SMOOTH, LOW LYING WITH BARRIER ISLANDS, MARSHES	HIGH LAND CLOSE TO SHORE, BLUFFS & BEACHES	HIGH LAND CLOSE TO SHORE, ISLANDS & BEACHES	ALL GLACIATED, EXCEPT IN N.W.	STEEP IRREG. BEACH
RIVER FLOW										
RUNOFF PER MILE OF TIDAL SHORELINE	16	15	15	16	3	52	7	77	NO DATA	NO DA
NUMBER OF MAJOR RIVER BASINS	5	6	6	12	0	21	8	9	16	0
TOTAL RUNOFF (CFS)	72,000	106,000	79,800	154,000	11,500	739,0	83,400	344,000	NO DATA	NO DA
SEDIMENTATION	NO DATA:									
QUANTITY OF SUSPENDED LOAD (1000 TONS/YR)	SEDIMENTATION NOT SEVERE PROBLEM - GREAT AMOUNT OF ROCK	15,300	8,640	53,100	NO DATA	342,600	24,00	1,7	NO DATA	NO DAT
CLIMATE (3)										
TEMPERATURE (DEG. F)										
MEAN	45	54	58	66	76	69	61	55	43	75
SUMMER	70	74	87	93	89	91	76	74	54	83
WINTER	17	35	30	40	64	45	43	35	5	67
PRECIPITATION (IN.)										
TOTAL	43	42	44	50	46	55	12	42	53	24-14
SNOW, ICE	72	16	23	0	0	0	0	7	90	0
TIDE (3)										
TYPE	EQUAL SEMI-DIURNAL	EQUAL SEMI-DIURNAL	EQUAL SEMI-DIURNAL	EQUAL SEMI-DIURNAL	EQUAL SEMI-DIURNAL	DIURNAL	UNEQUAL SEMI-DIURNAL	UNEQUAL SEMI-DIURNAL	UNEQUAL SEMI-DIURNAL	UNEQUA SEMI-DIURNA
MEAN RANGE (FT.)	10	5	2	5	2	2	5	7	20	2

(1) DATA GIVEN ARE FOR SOUTHEAST AND SOUTH COASTS ONLY.
(2) DATA ARE TYPICAL NEAR-COASTAL VALUES FOR THE REGION, EXCEPT FOR CHESAPEAKE BAY, WHERE DATA ARE FOR THE MIDDLE OF THE BAY.
(3) DATA ARE FOR A POINT TYPICAL OF THE REGION.
REFERENCE: THE NATIONAL ESTUARINE INVENTORY
DATA SOURCE U.S. COAST AND GEODETIC SURVEY, U.S. GEOLOGICAL SURVEY, U.S. WEATHER BUREAU

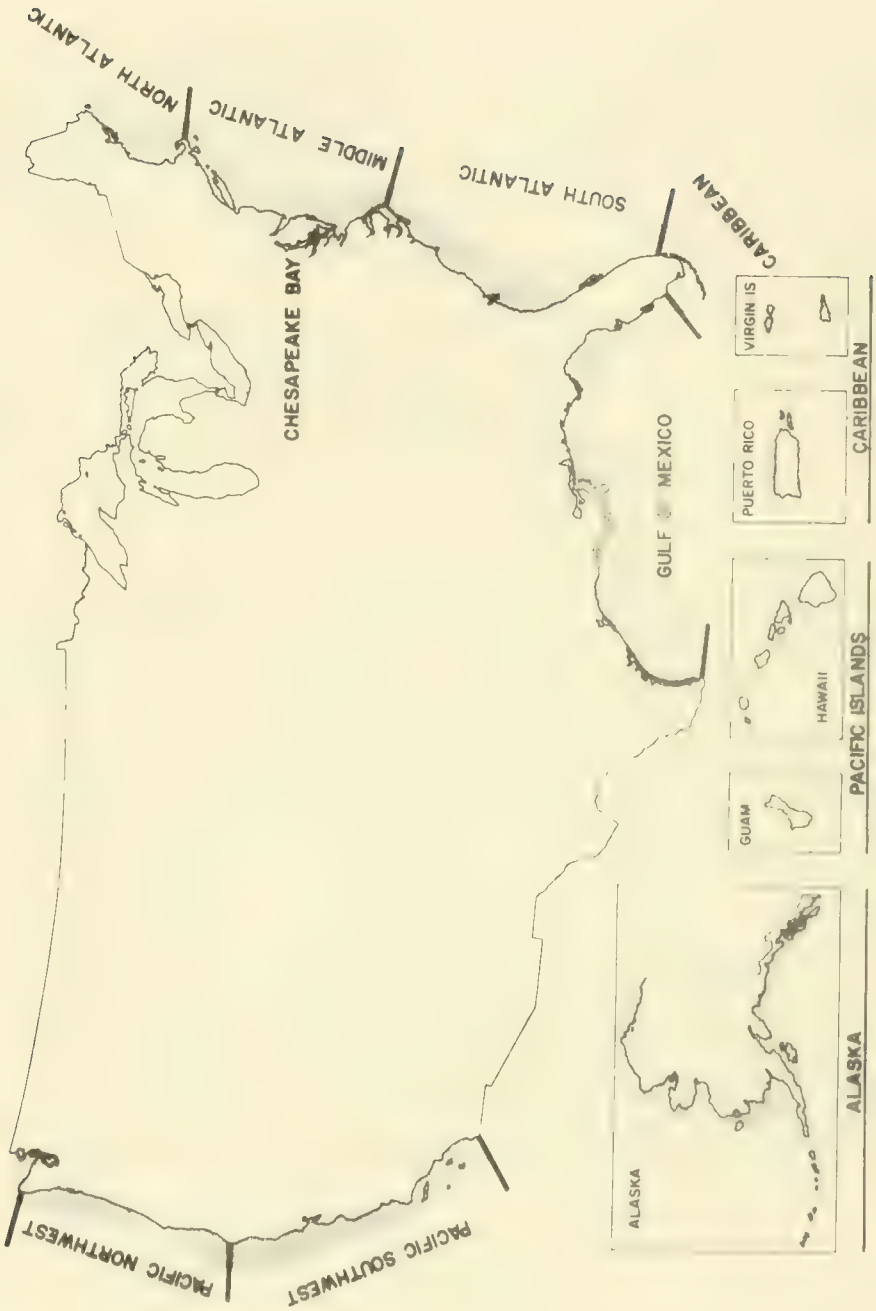

Figure IV I 19
BIOPHYSICAL REGIONS OF THE UNITED STATES

Cool, fertile waters with a large tidal range strike a steep, indented coast with deep water close inshore, but protected from the full force of the ocean waves by a wide continental shelf. Moderate precipitation with heavy snowfall leads to heavy spring river runoff which dominates local circulation. Natural erosion and sedimentation are not severe problems, and the evolution of drowned river valley estuaries is in an early stage in this region.

Middle Atlantic Estuarine Region: Cape Cod to Cape Hatteras, exclusive of Chesapeake Bay.

A wide, gently sloping continental shelf with a smooth shoreline is cut by the entrances of several major river systems carrying moderate amounts of sediments. The same cool, fertile waters as in the North Atlantic estuarine region wash this coastline but with a smaller tidal range. The evolution of drowned river valleys into coastal marshes is in a secondary stage in the larger estuarine systems, with sand spits and barrier islands forming.

Chesapeake Bay Estuarine Region: All of the Chesapeake Bay system from Cape Charles and Cape Henry inland.

Isolation from direct oceanic effects in much of the greatly branched system, the many subsystems with major river flows, and the reduced concentration of the ocean salt throughout the

Bay and its tributaries make this a unique estuarine system. This is a drowned river valley with numerous similar tributary systems in various stages of evolution.

South Atlantic Estuarine Region: Cape Hatteras to Fort Lauderdale, Florida (about 26° North Latitude).

The generally wide continental shelf is brushed by the warm waters of the well-defined Gulf Stream. The low-lying coastal plain terminates in barrier islands and marshes in which large amounts of sediments are being continually deposited by moderate sized rivers fed by heavy summer rainfall. Many of the drowned river valley estuaries have evolved all the way to coastal marshes. Tidal ranges are small to moderate, depending on local conditions.

Caribbean Estuarine Region: Fort Lauderdale to Cape Romano (the Florida penisula south of 26° North Latitude), plus Puerto Rico and the Virgin Islands.

High temperatures, heavy rainfall, and warm ocean currents along practically nonexistent continental shelves result in tropical estuarine environments throughout this region. Coral reefs and mangrove swamps are the typical coastal features of south Florida, while the islands are mountainous and are fringed with coral reefs and beaches. Tidal ranges are small.

Gulf Estuarine Region: Cape Romano to the Mexican border.

A wide continental shelf extends all the way around this large embayment, in which warm tropical waters are moved gently by weak currents and small tidal ranges. Heavy rainfall over most of tne area brings sediments from the broad coastal plain to be deposited in the estuarine zone. Most of tne drowned river valleys nave evolved to a point intermediate between those of the Middle and South Atlantic Regions -- barrier islands are extensive and have large shallow bays behind them.

The Missippi forms one of tne major deltas of the world. This delta is unique among the estuarine systems of the United States, both in its size and in the extent to which it has built out over the continental shelf.

Pacific Southwest Estuarine Region: Mexican border to Cape Mendocino.

Because of tne narrow continental shelf, perodic upwelling of deep water close inshore as winds force the California current offshore brings cool, fertile water near the coast for several months of the year. The coastline has a typical beach and bluff configuration with only a few shallow embayments and the unique earthquake-born valley of San Francisco Bay which, in tne delta formed by tne confluence of the San Joaquin and Sacramento Rivers, show what erosion and sedimentation might

have done along the southwest coast if rainfall were greater in that area (Figure IV.1.20) of easily erodable mountains.

Pacific Northwest Estuarine Region: Cape Mendocino to the Canadian border.

The continental shelf and coastal configurations are similar to those of the Pacific Southwest, but ocean water temperatures are lower here; the movement of the California current away from the coast is not as pronounced, and heavier rainfall has resulted in some major rivers cutting through the coastal mountains to form deeply embayed estuarine systems. See Figure IV.1.21. Extensive erosion and sedimentation have caused wide tidal flats, bars, and shoals to be typical of these systems.

The straits of Jual de Fuca and Puget Sound, which were glacier-formed, do not have as severe sedimentation as exists along the ocean coast, and have retained much of their original configuration.

Alaska Estuarine Region: All of Alaska including the Aleutian and Bering Sea Islands.

The dominant factors in this region are temperature and precipitation. Water temperatures are near freezing, and much of the precipitation falls as snow. The continental shelf is wide all through the region, and tide ranges are very large. The

southeast and south coasts have active glaciation and consist primarily of glacier-cut embayments and fjords; the west and north coasts are much flatter and have been modified to some extent by sediments eroded from the interior, including glacial silt, and by the grinding action of pack ice during winter.

Pacific Islands Region: The Hawaiian Islands, American Samoa, Guam.

This region consists of tropical ocean islands of volcanic origin. Dominating factors are lack of a continental shelf, full exposure to oceanic conditions, and pleasantly warm temperatures. Coral reefs and beach and bluff configurations are typical (Figure IV.1.22).

MANAGEMENT AND THE BIOPHYSICAL REGIONS

The environmental factors upon which this subdivision of the national estuarine system is made all represent transport of solar or gravitational energy to the estuarine zone. Inherent in this subdivision is acceptance of the fact that the input of energy--upon which all life is based--differs in quantity and type in the several regions of the estuarine zone.

In managing estuaries for human benefit, these regional differences in energy form and quantity represent the environmental realities within which management must operate. In the fullness of time and with greater understanding of the world it may

be possible to modify the environmental conditions to some extent, but for the present the existing environmental limitations must be accepted.*

This discussion has so far considered only those environmental factors which dominate the estuarine environment, not the environment itself. Management's fundamental concerns, however, are with the appearance and quality of the individual environment and with the variety and usefulness of the life forms a particular environment will support.

There are many life forms which exist throughout the estuarine zone, most of them being particularly adaptable forms of plankton, crustaceans, and fish. In addition to these, however, there are some less adaptable life forms which require a limited range of conditions to survive and yet others which need a very specific environment to reproduce.

Maine lobsters, for example, are numerous in the North Atlantic estuarine region, scattered in the Middle Atlantic, and cannot be found in other regions. The commercial shrimp, on the other

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*One environmental factor, river flow, is already being freely modified--sometimes with less understanding than may be desirable. A case study on damages associated with river flow modification in Charleston Harbor is presented in Chapter 5 (IV-1-3).

hand, are abundant throughout the Gulf, Caribbean, and South Atlantic Regions, but sparse beyond this range. Maine lobsters thrive in the cold Labrador current waters, while the major commercial species of shrimp need warm waters like those of tne Gulf Stream to reproduce.

Within the general range of the regional estuarine environment are specific local conditions with which management in particular estuarine systems must deal. The next part of this discussion considers local conditions of land and water interaction and their relationship to the living communities present.

SECTION 4. THE LAND AND THE WATER

Nowhere on the Earth's surface are land and water as intimately related as in the estuarine zone, and nowhere are their interactions so significant in the ultimate effect on man's environment.

Concern with the quality of the environment is couched ultimately in terms of its effect on life forms--whether it is safe for human beings to be near, whether it looks clean, and whether desirable aquatic life forms can live and reproduce in it. These conditions are measured in terms of the magnitudes of water quality parameters which tell indirectly what the water quality is. These magnitudes depend not only upon the character and concentrations of waste materials, but also upon the rapidity with which a particular system can purge itself of damaging agents.

The shape of land along the land-sea interface goes far toward determining what water movement and circulation patterns exist in particular local areas, and, consequently, how fast a particular estuarine system will rid itself of pollutants. Within the estuarine regions discussed in the preceding section, different structural types define patterns of water movement typical of particular structures, no matter what the external environment may be.

MORPHOLOGY OF THE ESTUARINE ZONE

Those characteristics shown in Table IV.1.6 describe differences in structure and form of the estuarine zone among the estuarine regions. The descriptive ratios presented in this table result from combining areas and distances characteristic of the estuarine zone of each region. Such ratios are numerical indices of the relative sizes of the estuarine zone in each region and also give quantitative measures of its relative composition among regions. Their greatest value, however, is in comparing individual estuarine systems so as to apply the lessons learned in one estuary to the problems of another.

Alaska has by far the longest general coastline and tidal shoreline as well as the greatest estuarine water area of any estuarine region, but the Chesapeake Bay region has a much greater proportion of estuarine shoreline and area for its size than any of the other regions. Estuarine systems within the Chesapeake Bay region consist of a group of branched rivers entering the Chesapeake Bay itself, which is in turn the former valley of the Susquehanna River. The estuarine systems on the western side of the Bay tend to be surrounded with somewhat hillier land and less extensive marsh areas than those on the eastern shore, though nearly all systems tributary to the Bay are drowned river valleys.

TABLE IV.1.6 SIZE AND SHAPE COMPARISONS AMONG BIOPHYSICAL REGIONS

	NORTH ATLANTIC	MIDDLE ATLANTIC	CHESA-PEAKE BAY	SOUTH ATLANTIC	CARIB-BEAN	GULF OF MEXICO	PACIFIC SOUTH-WEST	PACIFIC NORTH-WEST	ALASKA	PACIFIC ISLANDS	TOTAL
OCEAN COASTLINE (MILES)	1358	1286	11.3	817	1542	2270	1194	669	14899	1194	25233
TIDAL SHORELINE (MILES)	4419	7992	5469	9793	3437	15476	3060	4793	33904	1323	89571
ESTUARINE WATER AREA (SQ.MILES)	3401	5130	4554	3973	717	10944	799	1946	14353	15	45832
MARSH AREA (SQ.MILES)	97.6	603.1	595	2267	616.4	8427	191	44.5	NO DATA	15	12841
COASTAL COUNTIES AREA (SQ.MILES)	11177	19237	13859	24839	9869	48151	31168	42768	334413	6703	552184
DESCRIPTIVE RATIOS:											
TIDAL SHORELINE / OCEAN COASTLINE	3.3	6.2	408.0	12.0	2.2	6.8	2.6	7.2	2.3	1.1	3.5
ESTUARINE WATER AREA / OCEAN COAST-LINE	2.5	4.0	400.0	4.9	.46	4.8	.67	2.9	.96	.01	1.8
ESTUARINE WATER AREA / TIDAL SHORE-LINE	.77	.64	.83	.41	.21	.71	.26	.41	.42	.01	.5
MARSH AREA / OCEAN COASTLINE	.07	.47	53.0	2.8	.40	3.7	.16	.07		.01	.3
MARSH AREA / TIDAL SHORELINE	.02	.08	.11	.23	.18	.54	.06	.01		.01	.1

REFERENCE: NATIONAL ESTUARINE INVENTORY

DATA SOURCES: U.S. COAST AND GEODETIC SURVEY, BUREAU OF THE CENSUS

The Middle Atlantic and Gulf estuarine regions have about equal amounts of tidal shoreline and estuarine water areas per mile of ocean coastline, but in the Middle Atlantic region the estuarine zone consists primarily of a few large drowned river valley embayments (e.g. New York Harbor, Delaware Bay, and Narragansett Bay) and some small marsh amd barrier beach systems receiving only coastal fresh-water runoff. The estuarine zone of the Gulf region on the other hand, consists mainly of moderate sized embayments with barrier beaches and extensive marshes, but receiving river flow from upland drainage areas and representing an intermediate state in the evolution of drowned river valleys into coastal marshes in the Gulf region.

The North Atlantic is unlike any of the other regions in overall structure, but is similar to Puget Sound and Southeast Alaska. Characteristic of the North Atlantic region are very irregular, hilly coastlines with deep water close inshore and long, narrow embayments with open access to the sea.

The South Atlantic region has two dominant types of estuarine structure. From Cape Hatteras to about Jacksonville, there is a general input of upland river drainage to the estuarine zone and the estuarine systems are typical drowned river valleys in the later stages of evolution represented by barrier beaches or coastal marshes backed by extensive swamps. South of Jacksonville fresh-water runoff comes primarily from local coastal drainage,

and there are uniform and extensive barrier beaches or coastal marshes backed by extensive swamps. South of Jacksonville fresh-water runoff comes primarily from local coastal drainage, and the there are uniform and extensive barrier island beaches with long narrow embayments behind them. Continuous but generally narrow strips of marsh lie along the embayments. This structure fades into the extensive swamplands of the Everglades farther down the Florida peninsula.

Both the Pacific Northwest and Pacific Southwest regions have few estuaries. The estuarine systems of the Northwest Pacific region tend to be the mouths of rivers which have cut their way through coastal mountain ranges, either of their own accord of aided by glaciers as in the case of Puget Sound. Shallow coastal embayments with little and sporadic river flow are characteristic of the few estuarine systems of the Southwest, except for San Francisco Bay, which receives fresh water runoff from much of central California.

Alaska presents the greatest variety in estuarine form and structure of any of the estuarine regions. Nearly all kinds of systems typical of other regions are found there. In addition, Alaska has the only glaciated coast and most of the fjords found in the United-States.

The rivers entering the estuarine zone drain nearly 90 percent of the U. S. land area. They carry to the sea sediments eroded from this vast expanse and deposit much of it in the narrow band of 274

counties which comprise the basic political subdivisions of the estuarine zone. These coastal counties form a strip of land averaging about 50 miles wide along the coast, except where the large embayments of the Chesapeake Bay and Puget Sound make this strip reach more than 100 miles from the ocean.

The total area of the coastal counties is 552,000 square miles with the bulk of this in the Alaskan estuarine region and the smallest part in the Pacific Island estuarine region. In the Middle Atlantic, South Atlantic, and Gulf regions, the coastal strip is a low-lying plain composed of easily erodable materials which tend to be deposited in the estuarine zone and moved about by waves and currents. The ocean coast is mostly sand throughout these regions, overlain near river mouths by some mud and clay. The Mississippi delta is entirely mud, clay, silt, and sand washed down from the heartland of the continent. Sand, mud, and clay predominate in the embayments, with sand characteristic of open waters and mud common in marshes.

Rock, gravel, and sand are the common bottom materials along the North Atlantic coast, with the rock overlain by fine mud and silt in confined areas and sand common in the offshore areas.

The Pacific coast counties form mountainous strips along the coast. Sediments reaching the ocean in this region tend to be deposited in broad tidal flats or bars where currents permit, or washed off into the ocean where wind and waves motion is suffi-

ciently vigorous. Bottom sediments are rock and clay covered in some places with fine mud.

The characteristic sediment of the Alaskan estuarine region is glacial flour, that extremely fine material ground from the land and carried along by glaciers. Many of the estuaries and much of the continental shelf off the western Alaskan coast are covered with this material.

Coral reefs, sand, and rocks are typical of estuarine bottoms in the Pacific and Atlantic Islands. Except in extremely sheltered areas, sediments are rare because of the continuous wind and wave action.

A MORPHOLOGICAL CLASSIFICATION OF THE ESTUARINE ZONE

The estuarine zone can be classified according to its local morphology into major categories, several of which exist in each of the estuarine biophysical regions. Within each of these categories, the similarities in structure reflect similarities in water movement, water quality, and ecology which make it possible to apply lessons learned in managing an estuarine system in one region to similar estuarine systems in other regions.

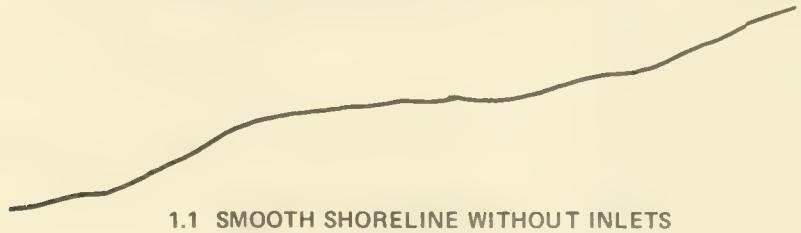
Figure IV.1.23 illustrates each category. Table IV.1.7 shows the numbers of different kinds of estuarine systems in each estuarine biophysical region. Unrestricted river entrances and embayments dominate and are rather evenly distributed throughout all the regions.

TABLE IV.1.7 A MORPHOLOGICAL CLASSIFICATION OF THE NATIONAL ESTUARINE ZONE BY DOMINATING CHARACTERISTIC (NUMBERS OF TYPES IN EACH BIOPHYSICAL REGION)

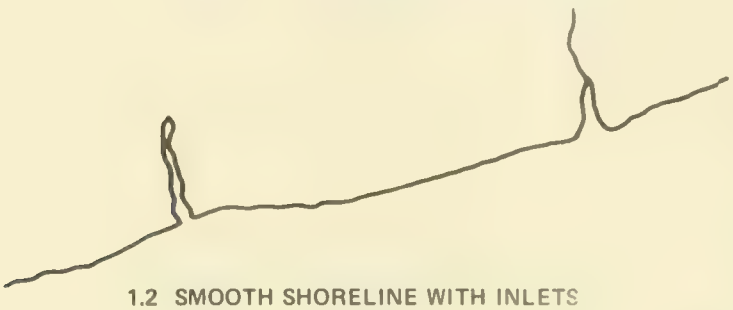
CLASSIFICATION TYPE	NORTH ATLANTIC	MIDDLE ATLANTIC	CHESA-PEAKE BAY	SOUTH ATLANTIC	CARRIBEAN	GULF OF MEXICO	PACIFIC SOUTH-WEST	PACIFIC NORTH-WEST	ALASKA	PACIFIC ISLANDS	TOTAL
SMOOTH SHORELINE											
WITHOUT INLETS	1	2			1	1	9			11	25
WITH INLETS	2	7		7		1		5	2		24
WITH SMALL EMBAY-MENTS	3	8		9		11	6	7	5	14	64
INDENTED SHORELINE											
WITHOUT ISLANDS	10	4			15	1			10	2	43
WITH ISLANDS	15	5		2	2	1	1	1	33		60
MARSHY SHORELINE		3	1	6	1	13					24
UNRESTRICTED RIVER ENTRANCE	7	7	7	8		34	8	21	2		94
EMBAYMENT											
WITH ONLY COASTAL DRAINAGE	8	24	136	41	4	91	21	3	12	9	349
WITH UPLAND RIVER INFLOW	17	23	18	12	2	54	19	27	23		195
FJORD								2	4		6
TOTAL	63	83	162	85	26	207	64	66	92	36	884

REFERENCE: THE NATIONAL ESTUARINE INVENTORY
DATA SOURCE: FWPCA

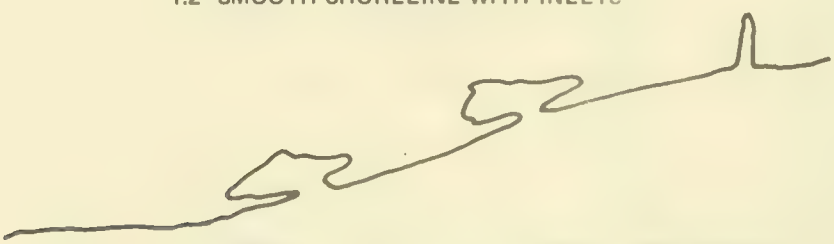
FIGURE IV.1.23 MORPHOLOGICAL CLASSIFICATION OF ESTUARIES AND ESTUARINE ZONES



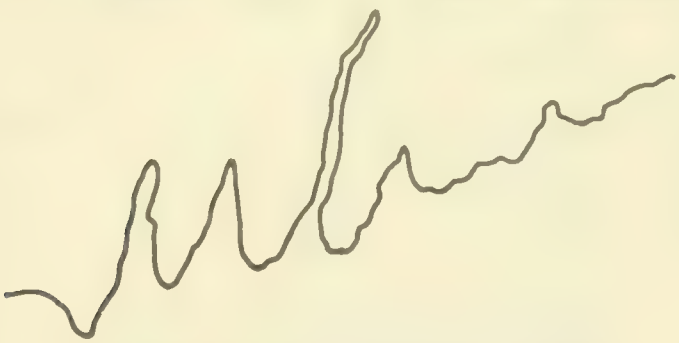
1.1 SMOOTH SHORELINE WITHOUT INLETS



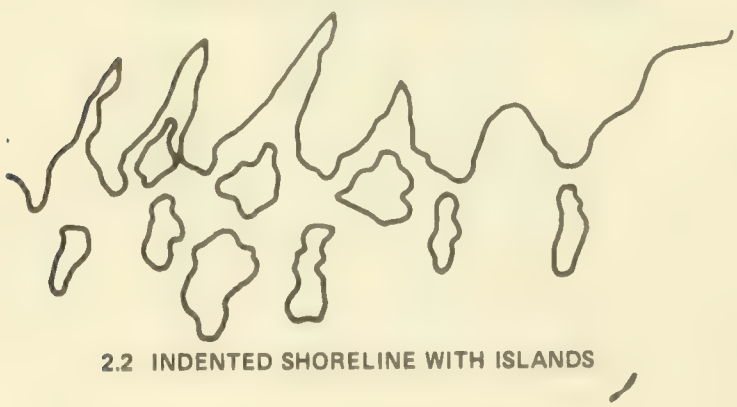
1.2 SMOOTH SHORELINE WITH INLETS



1.3 SMOOTH SHORELINE WITH SMALL EMBAYMENTS



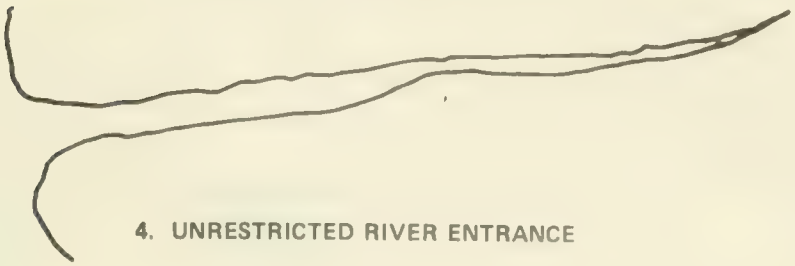
2.1 INDENTED SHORELINE WITHOUT ISLANDS



2.2 INDENTED SHORELINE WITH ISLANDS

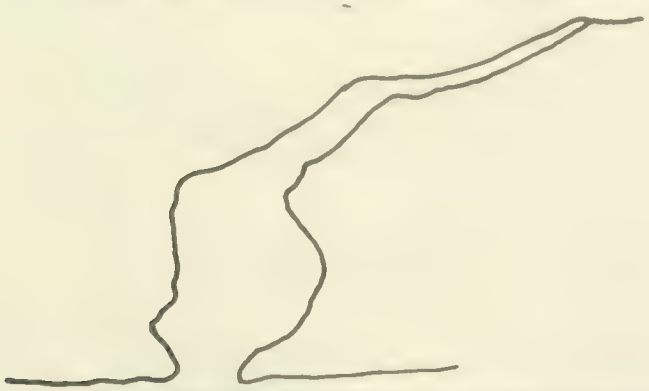
FIGURE IV.1.23 MORPHOLOGICAL CLASSIFICATION OF ESTUARIES AND ESTUARINE ZONES (continued)

3. MARSHY SHORELINE



4. UNRESTRICTED RIVER ENTRANCE

5.1 EMBAYMENT WITH ONLY COASTAL DRAINAGE



5.2 EMBAYMENT WITH CONTINUOUS UPLAND RIVER INFLOW

6. FJORD

with the common type of estuarine system being a coastal embayment with drainage from only the local coastal area. Many of these latter embayments have large marsh areas, but the Middle-Atlantic, South Atlantic, and Gulf are the regions in which marshes are the predominant feature in some parts of the estuarine zone.

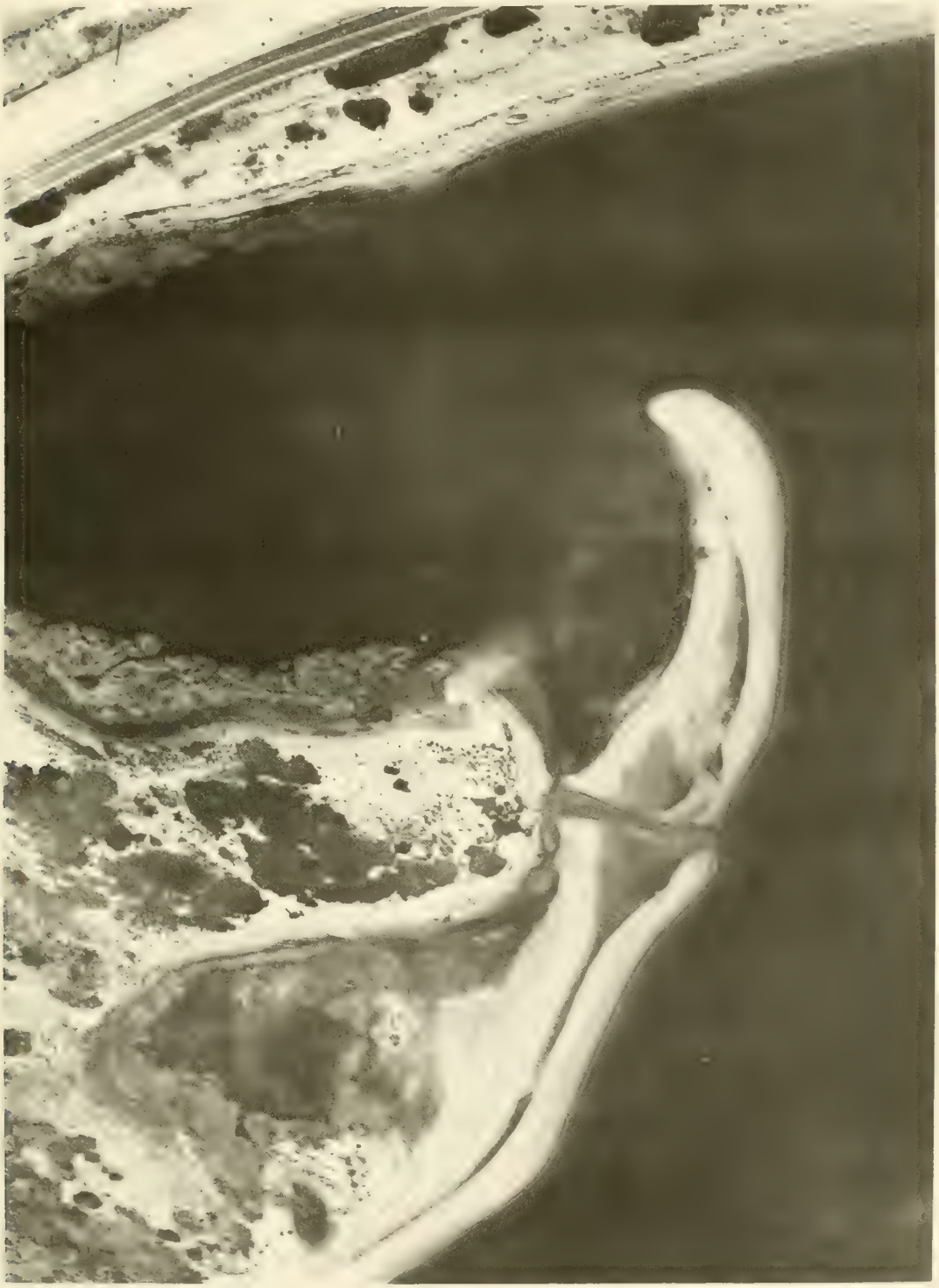
WATER MOVEMENT IN THE ESTUARINE ZONE

The unique nature of water movement and circulation patterns in the estuarine zone is the result of the meeting and mixing of fresh river water and salty ocean water of slightly greater density under the oscillating influence of the tide. There may be additional complicating factors such as temperature and wind action, but the resulting circulation nearly always reflects the interaction of river flow and estuary shape with the tidal flow of the ocean water.

General water movement patterns are predictable for each category of estuarine shape. Where there is little or no fresh water inflow, water moves toward and away from the shore, being reflected into currents paralleling the shore in some cases. On ocean beaches, this parallel type of water movement builds sandspits and barrier islands to begin the transformation of drowned river valleys into embayments and coastal marshes, as illustrated by Figure IV.1.24.

Where fresh water runoff reaches the sea as a series of small

FIGURE IV.1.24 SAND SPIT BUILDUP (SANDY HOOK BAY, N.J.)



COURTESY OF T.R. AZAROVITZ AND U.S.B.S.F. & W., SANDY HOOK MARINE LAB.

streams or as seepage across the surface, coastal marshes often form and circulation patterns are weak and undefined. This situation may exist where local coastal drainage runs off to the sea, where a drowned river valley has filled in so much that the river channel is no longer defined, or where sediment deposition at the mouth of a large river forms a delta (Figure IV.1.6).

Fjords are formed where a glacier, having gouged out a deep embayment, melts as it reaches the sea and deposits the entrained dirt and rock as a shallow sill across the entrance of the embayment (Figure IV.1.25). This sill isolates the lower water of the fjord from the sea; the only significant water movement is in the layers above the sill level.

It is where moderately large rivers and streams meet the sea that the unique estuarine circulation patterns occur most frequently. Large fresh water flows in well-defined channels tend to slide over the top of denser sea water without rapid mixing. Water movement in such cases exhibits various degrees of stratification.

Narrow channels and high fresh water flows result in a well-defined sea water layer moving upstream along the bottom of the channel and a nearly fresh layer moving toward the sea along the surface (Figure IV.1.26).

The Mississippi and Savannah Rivers are classic examples of this "salt-wedge" circulation pattern. With this type of water movement, salt and water from the bottom layer mix constantly into

Figure IV.I.25

CIRCULATION IN A TYPICAL FJORD

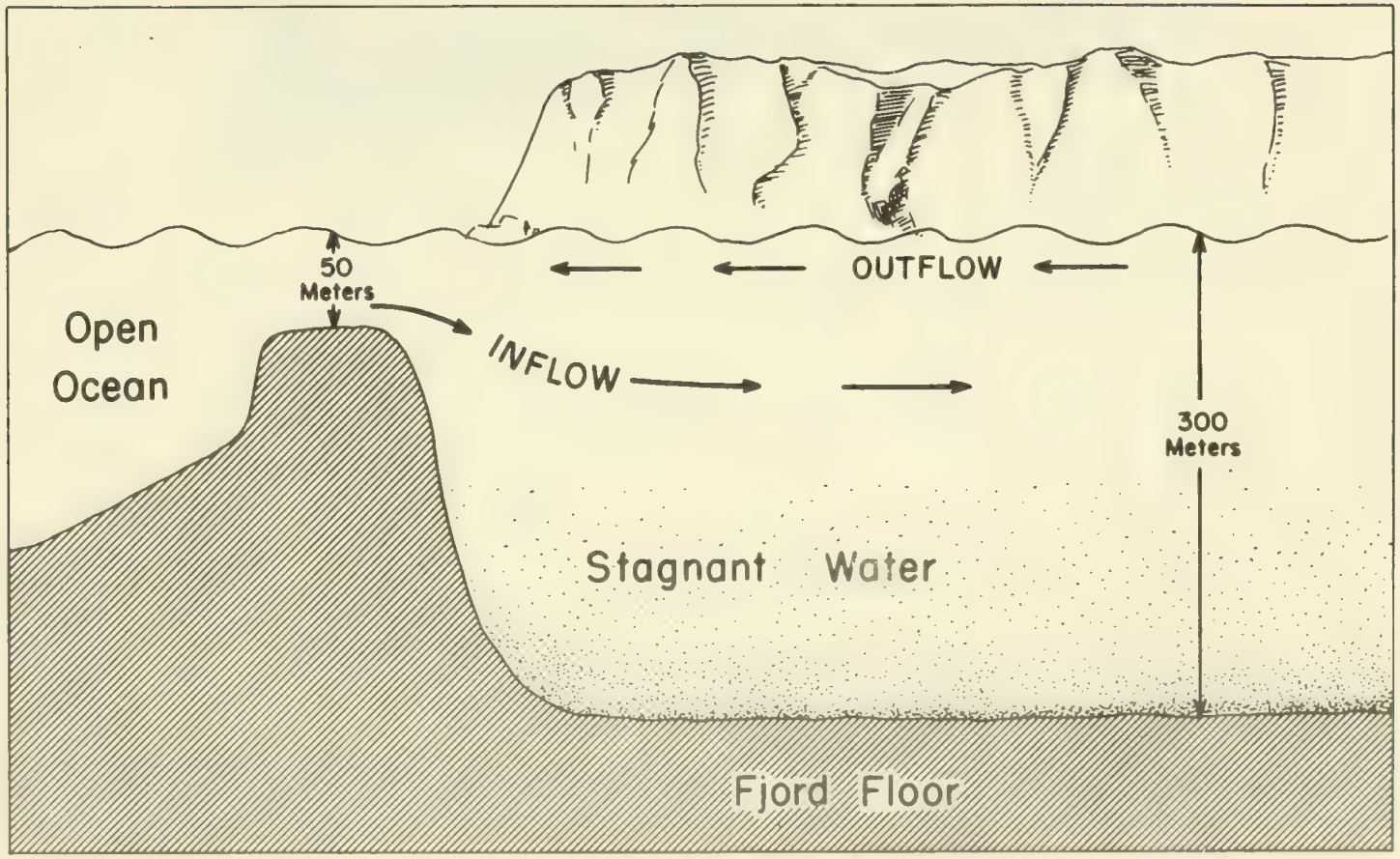
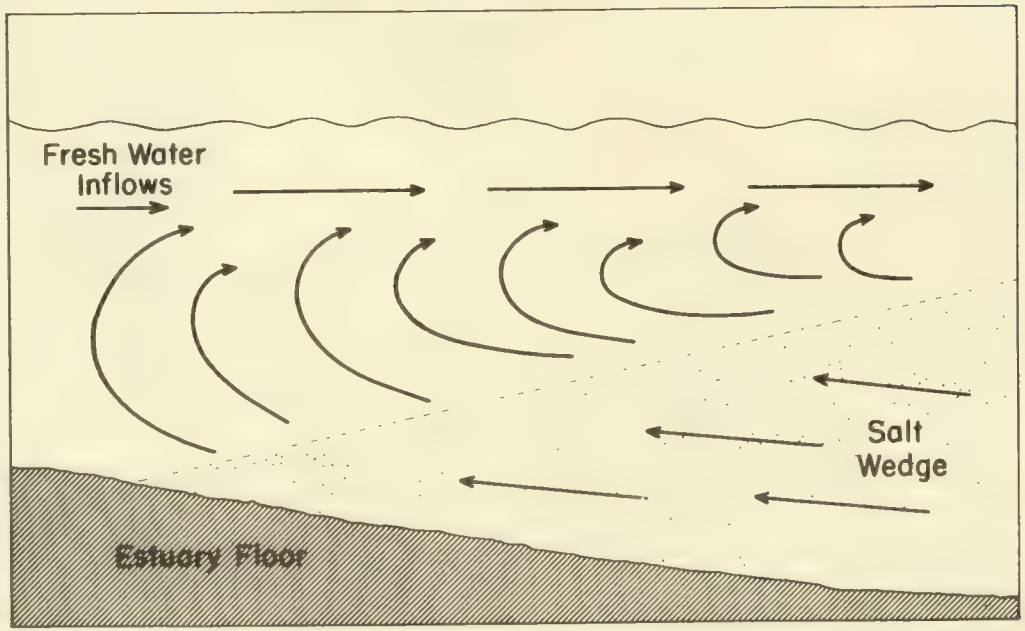


Figure IV.I.26

TYPICAL SALT WATER WEDGE CIRCULATION PATTERN



The Mississippi and Savannah Rivers are classic examples of this "salt-wedge" circulation pattern. With this type of water movement, salt and water from the bottom layer mix constantly into the top layer, and more salt water flows in from the sea to replace it so that the total amount of water in motion may be many times the river flow plus the tidal flow. Such estuarine systems purge themselves very rapidly of waste discharges.

With wider channels, smaller river flows, and greater tidal ranges more mixing occurs and other forces come into play. Embayment shape, bottom configuration and material, and the effects of the Earth's rotation all may play a role. In some estuarine systems of this type, the degree of stratification may change with changes in river flow, temperature, wind, or other transient conditions.

The James River is a drowned river valley in the Chesapeake Bay Estuarine Region (Figure IV.1.27). Its length of tidal influence is great in proportion to its width, and it exhibits some vertical stratification. Delaware Bay is much wider than the James and is stratified laterally (Figure IV.1.28); that is, salt content along the eastern shore tends to be higher than that along the western shore. This phenomenon probably results from forces, associated with the Earth's rotation, which in large bodies of water tend to cause lateral stratification as a result of the different rates of slipping of salt and fresh water on the spinning earth's surface.

Hillsborough Bay, an arm of Tampa Bay, is nearly unstratified and quite salty during much of the year. During high flows, however, the Hillsborough River pushes the salt out of the upper part of the Bay and often kills heavy growths of a salt water plant which is not tolerant of fresh water.

Some very large embayments with small ocean entrances such as Pamlico Sound have very small tidal ranges, very little stratification, and throughout most of their area, very weak currents (Figure IV.1.4). Only at the channels to the ocean are currents strong, and there they are often extremely violent and dangerous. Wastes discharged into such embayments tend to remain for long periods and exert their effects in the estuary rather than moving out to sea.

NATURAL WATER QUALITY IN THE ESTUARINE ZONE

Estuarine water quality is the product of both land and water. From the land, erosion and solution in river water bring suspended and dissolved minerals, while decaying vegetation adds dissolved organic material. Sea water itself contains three percent dissolved salts, but negligible quantities of organic matter.

In the estuarine zone these two different solutions meet and mix. Salt concentrations range from that of the oceans to the almost unmeasurable amounts present in some rivers. Where little stratification exists, sea salt dominates mineral concentrations in estuarine

waters; in stratified systems, however, the small amounts of minerals entering in the fresh water may be as important in some parts of the estuarine zone as the much larger concentrations from the sea are in others. The interface between fresh and salt water is a region of complex chemistry where some material may be precipitated out or otherwise changed, much as lye soap used to be "salted out" when soap was made by boiling lard with wood ash extract in the backyard. Organic matter from decaying vegetation is particularly susceptible to this type of chemical effect.

Climate also plays a direct role in determining estuarine water quality. Excessive evaporation can drive salinities far above those of ocean water, as in Laguna Madre, and create an inverse estuarine system. Sunlight beating down on shallow embayments may raise temperatures so high that use of the estuarine waters for cooling may be seriously impaired.

Table IV.1.8 summarizes ocean and river water quality in each of the estuarine regions. Ocean water quality itself varies in different areas off the coast, generally reflecting ocean currents and climate as discussed earlier. Ocean temperatures reflect not only the variation in latitude, but also the temperature differences of the cold and warm currents around the coast. The temperature difference north and south of Cape Hatteras is particularly striking, because the Gulf Stream and Labrador Current water each dominate on one side of the Cape.

TABLE IV.1.8 NATURAL OCEAN AND RIVER WATER QUALITY TYPICAL OF THE ESTUARINE ZONE

BIOPHYSICAL REGION	OCEAN WATER QUALITY						RIVER WATER QUALITY					
	TEMP. DEG.F.	DIS-SOLVED OXYGEN (PPM)	PH	SALIN-ITY (CL-) (PPM)	PHOS-PHATE PHOS-PHORUS (PPM)	NITRATE NITRO-GEN (PPM)	TEMP. DEG.F.	DIS- * SOLVED OXYGEN (PPM)	PH	SALIN-ITY (CL-) (PPM)	PHOS-PHATE PHOS-PHORUS (PPM)	NITRATE NITRO-GEN (PPM)
NORTH ATLANTIC												
SUMMER	65	7.93	8.15	17989	0.124		72	7.51	6.3	1.0	.05	0.7
WINTER	32	8.22	8.15	17989			32	12.43	6.7	3.0	.06	0.2
MIDDLE ATLANTIC												
SUMMER	73	6.34	7.62	17385	1.053	0.283	71	7.60	7.5	9.5	.21	4.6
WINTER	36	7.17		14022			35	11.99	7.1	12.0	.03	1.1
CHESAPEAKE BAY												
SUMMER	80	6.60	7.66	10266	1.425	0.056	80	6.94	7.0	9.5		0.6
WINTER	38	8.13	7.53	7922	0.712		40	11.00	6.9	11.0		3.4
SOUTH ATLANTIC												
SUMMER	87	6.66	8.17	19723	0.434		76	7.18	7.0	5.0	.14	1.5
WINTER	50	6.74	8.00	19839	1.084		55	9.16	4.9	6.2	.25	0.5
CARIBBEAN												
SUMMER	87	6.70	8.10	19723	0.341		83	6.65	7.4	44.0	.12	
WINTER	71	6.33	7.99	19906	0.434		61	8.30	8.2	60.0		0.7
GULF OF MEXICO												
SUMMER	87	6.52	8.03	19424	0.712		78	5.80	7.7	5.0	.00	0.6
WINTER	54	7.39	8.24	19945	0.372		57	8.99	5.9	6.0		1.2
PACIFIC SOUTHWEST												
SUMMER	69	8.20	8.05	18504	2.571		68	7.79	8.0	6.7		1.4
WINTER	56	7.90	8.20	18499	2.292		46	10.29	8.1	4.8		0.9
PACIFIC NORTHWEST												
SUMMER	56	8.02	7.56	16017	5.049	0.812	74	7.29	7.5	3.0	.25	0.3
WINTER	45	8.76	8.33	14770	6.721		46	10.29	7.9	2.0	.11	0.3
ALASKA												
SUMMER	55	10.09	7.31	17596	2.013	0.042	52	9.23	7.5	3.2		0.5
WINTER	30	3.84	7.81	17706		NO	WINTER	DATA	AVAIL-	ABLE		
PACIFIC ISLANDS												
SUMMER	81	6.90	8.24	19307	0.898		NO	DATA	AVAIL-	ABLE		
WINTER	73	6.97	8.23	19396	0.558							

* VALUES ESTIMATED AT 85% SATURATION.

REFERENCE: THE NATIONAL ESTUARINE INVENTORY

DATA SOURCES: NATIONAL OCEANOGRAPHIC DATA CENTER, FWPCA

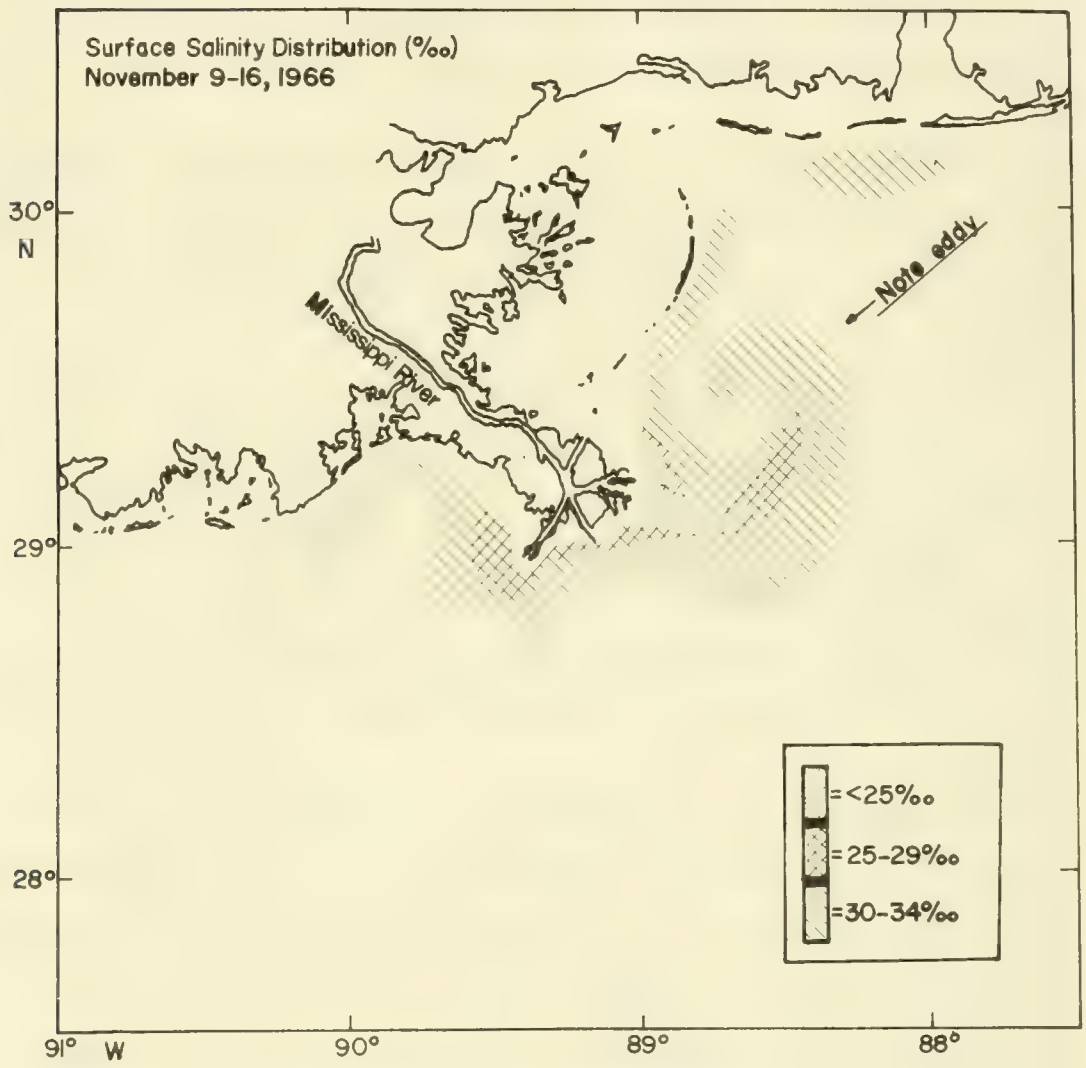
Nearshore ocean surface salinities are strongly influenced by river runoff and local precipitation. The effects of the Mississippi on the Gulf of Mexico are shown in Figure IV.1.29. Less dramatic, but nonetheless significant, are the effects of the Hudson on the Atlantic and of the Columbia on the Pacific.

The turbidity of ocean water is generally low except where it meets the shore; there the amount of turbidity is a direct reflection of the intensity of wave action and the nature of bottom material.

Dissolved oxygen is essential for all aquatic life. The amount of dissolved oxygen present in surface ocean water is very close to the total amount the water can contain. Since this saturation concentration depends on both temperature and salt concentration, the warm, saline waters of the Gulf contain far less oxygen than the cold, relatively fresh waters off the Alaskan coast.

The natural quality of water free from human impact in the rivers entering the estuarine zone depends primarily on the nature of the ground over which they flow. Minerals enter the water by dissolving from soil and rock as the water flows over it or carries it along. Water flowing over limestone or other sedimentary material usually has greater concentrations of dissolved minerals than water flowing over volcanic rock and sand. Insoluble minerals are carried along as sediments, some dissolving slightly and others settling out in quiet reaches of the rivers or in the estuarine zone.

FIGURE IV.1.29 SURFACE SALINITY DISTRIBUTION AROUND THE MISSISSIPPI DELTA



SOURCE: Bureau of Commercial Fisheries, Galveston, Texas

Decaying plant and animal materials also dissolve into the flowing streams. These materials use oxygen in the decaying process and in some streams, particularly in swampy areas, very low dissolved oxygen concentrations are normal. Dissolved organic material frequently has a very intense yellow-black color which may make a water body appear jet black. This condition is common in the estuarine zones of the South Atlantic and Gulf regions.

Variable as estuarine water quality and water circulation are, estuarine waters in each of the estuarine regions have typical characteristics for different morphological categories. Table IV.1.9 outlines such typical natural estuarine zone conditions.

TABLE IV.1.9 CHARACTERISTIC NATURAL ESTUARINE ZONE CIRCULATION AND WATER QUALITY CONDITIONS

Bio-physical Region	(1) Smooth Shoreline	(2) Indented Shoreline	(3) Marshy Shoreline
North Atlantic	Deep near shore, oceanic water, longshore currents, some suspended sand and clay	Deep near shore, oceanic water, erratic tidal currents; eddies and tidal pools	Strong currents in many small channels through marsh, some turbidity, high oxygen
Middle Atlantic	Oceanic water, longshore currents; suspended mud, clay silt	Generally shallow, suspended mud and sand, oceanic water	Moderate currents in well-defined channels, high dissolved oxyganic material, little turbidity, high oxygen
Chesapeake	Longshore tidal currents highly variable salinities, small amounts of organic material,	Moderate tidal currents, highly variable salinities, some turbidity	Poorly defined channels, small currents, dissolved organic material, moderately fluctuation oxygen
South Atlantic	Primarily tidal and wave induced currents, oceanic water with mud, clay and silt	Moderate tidal currents, highly variable salinities, some turbidity	Small currents, high color, dissolved organics, highly variable oxygen, sometimes low, high temperatures
Caribbean	Clear ocean water, gentle currents, warm temperatures throughout the year	Clear ocean water, gentle currents, eddies, warmer than ocean	High dissolved organics, color, suspended mud, very small currents, hot
Gulf of Mexico	Clear, generally warm ocean water, longshore currents	Very small currents, ocean water with slight turbidity, warmer than ocean	High dissolved organics, color, very small currents, slightly turbid, very warm
Southwest Pacific	Strong wave action, cool oceanic water, some silt and clay turbidity	Moderate suspended solids, erratic currents, high oxygen, cool	High suspended solids, erratic tidal currents, warmer than ocean and rivers
Northwest Pacific	Strong wave action, cold ocean water, some silt and clay turbidity	Moderate suspended solids, erratic currents, high oxygen, cold	High suspended solids, erratic tidal currents, warmer than ocean and rivers
Alaska	Very cold oceanic water, usually ice, salinities slightly depressed	Very cold oceanic water, overlain by some fresh water, high oxygen	Very cold water, variable salinity, much fine silt, debris from freezing
Pacific Islands	Clear, warm ocean water, strong wave action	Clear ocean water, gentle currents, eddies, warmer than ocean	High dissolved organics, color, suspended mud, very small currents, hot

References:
(1) U. S. Coast and Geodetic Survey, Coast Pilots, Tidal Current Tables.
(2) U. S. Army Project and Study Reports.
(3) FWPCA Reports and unpublished data.
(4) National Estuarine Inventory.

TABLE IV.1.9 CHARACTERISTIC NATURAL ESTUARINE ZONE CIRCULATION AND WATER QUALITY CONDITIONS (continued)

(4) Unrestricted River Entrance	(5) Embayment, Coastal Drainage Only	(6) Embayment, Continuous Upland River Flow	(7) Fjord
Highly stratified, some turbidity, high oxygen, temperatures warmer in summer, colder in winter than ocean	Little turbidity, water of oceanic character; strong tidal currents through inlets	Little turbidity, high oxygen, may be stratified, upper layer fresh, with temperatures warmer in summer, colder in winter than the ocean	
Moderate stratification, suspended mud and silt, high oxygen, strong currents	Generally shallow, small tides, clear water with lowered salinity, high oxygen	Variable stratification, suspended mud and silt, high oxygen, small amounts of organic material	
Moderate stratification suspended mud and silt, high oxygen, strong currents	Generally shallow, small tides, clear water with lowered salinity, high oxygen	Variable stratification, suspended mud and silt, high oxygen, small amounts of organic material	
Strong stratification, high suspended mud and clay, strong currents, dissolved organics, moderate oxygen	Some color, small currents, generally shallow, high dissolved organics, highly fluctuating oxygen	Slight and variable stratification, river water cooler than ocean, slight color, some oxygen fluctuation	
Slightly turbid, strong currents, river cooler than ocean water	Very small currents, generally shallow, quite warm, clear ocean water	Slightly turbid, eddying currents, slight stratification, high oxygen	
Slightly turbid, strong currents, river cooler than ocean water	Very small currents except in inlet, shallow, warm, slight turbidity from sand and silt, highly fluctuating oxygen	Slight and variable stratification, river water cooler than ocean some oxygen fluctuation	
Strong stratification, offshore bar formation, cool, high oxygen	Some suspended silt, erratic currents, cool, high oxygen	Moderate to strong stratification, high suspended silt, strong currents, high oxygen, cool	
Strong stratification, offshore bar formation, cold, high oxygen	Some suspended silt, erratic currents, cold, high oxygen	Moderate to strong stratification, high suspended silt, strong currents, high oxygen, cold	
Strong currents, high suspended solids frequently glacial in origin, very cold	Very cold oceanic water, much ice, surface layer of fresh water, high oxygen	High turbidity with glacial debris, seasonal freeze-ups, strong currents during runoffs	Stagnant below sill depth, very little oxygen, high salinity hydrogen sulfide
Slightly turbid, strong currents, river cooler than ocean water	Very small currents, generally shallow, quite warm, clear ocean water	Slightly turbid, eddying currents, slight stratification, high oxygen	

SECTION 5. THE LIFE
ENERGY AND LIFE IN THE ESTUARINE ZONE

It is in the variety and diversity of estuarine life that the input of energy to the estuarine zone finds ultimate expression. Whether energy comes directly, as in the solar radiation stimulating photosynthesis, or whether it comes indirectly, as with tidal flows or wind and rain pounding on the shoreline, its absorption and conversion to other forms of energy (such as food) are essential steps in the continuation of life in the water, in the marshes, and on the land.

Energy input from gravitational forces, as illustrated by tidal action and river flow, depends primarily on local or regional conditions, but direct energy input from solar radiation depends largely on the latitude, the tropics receiving more energy per acre than the arctic. The relative amounts of energy entering an estuarine system govern the kinds of life found there, and natural ecosystems show systematic variations related to the sources and amounts of energy received.

Estuarine zones with strong mechanical energy inputs from waves, currents, tides, or river flows develop similar ecosystems no matter whether in the tropics or the arctic. Exposed ocean beaches at all latitudes have communities of burrowing animals such as snails, worms, clams, and crabs. Rocky sea fronts develop communities of attached algae and mollusks (Figure IV.1.30). Channels with strong currents develop firmly attached communities where bottoms are hard, and only

microbial life where sediments are constantly in motion or being deposited. Where, however, such energy inputs do not dominate the input of radiation solar energy, natural communities develop compositions typical of Tropical, Temperate, or Arctic latitudes.

Tropical systems (Figure IV.1.31) are subject to only slightly varying warm temperatures; light energy input is both greater and more regular than in other latitudes. Within this general group there are the sparse populations along coasts with deep clear water close inshore; the teeming and colorful populations of coral reefs; and the mangroves and the submerged grasslands associated with shallow, nutrient-laden water. Only the southern part of Florida and the islands are of this type.

Arctic systems are subject to wide fluctuation of sunlight and temperature but ice is the key factor. Ecological systems develop in, on and under the ice and in the fjords associated with glaciers. (Figure IV.1.32). Only a small part of Alaska includes estuarine systems of this type.

Temperature systems are subject to moderate solar energy inputs, temperatures that change regularly with the seasons, and generally larger tide ranges and more wave action than either tropic or arctic systems. Most of the estuarine systems of the United States lie in the temperate zone, and the balancing of solar energy input against mechanical energy input in this zone leads to a great variety of ecosystem types, even within small geographic areas.

The tropical coral reefs have their counterparts in oyster reefs where hard surfaces and constant currents exist, and where there is sufficient particulate food in the water. The mangroves and submerged grasslands also have their counterparts in extensive marshes and submerged algae and grass beds which are among the most productive parts of the estuarine zone (Figure IV.1.33).

There are also intertidal ecosystems of burrowing animals, such as clams, where bottoms are soft (Figure IV.1.16) and of attached animals and plants where they are not (Figure IV.1.34). The predominant influence of great amounts of river flow and the associated rapid salinity changes and stratification also result in ecosystems specific for different salinity zones or types of stratification. Where there is little river runoff, characteristic plankton and attached algae communities develop (Figure IV.1.35).

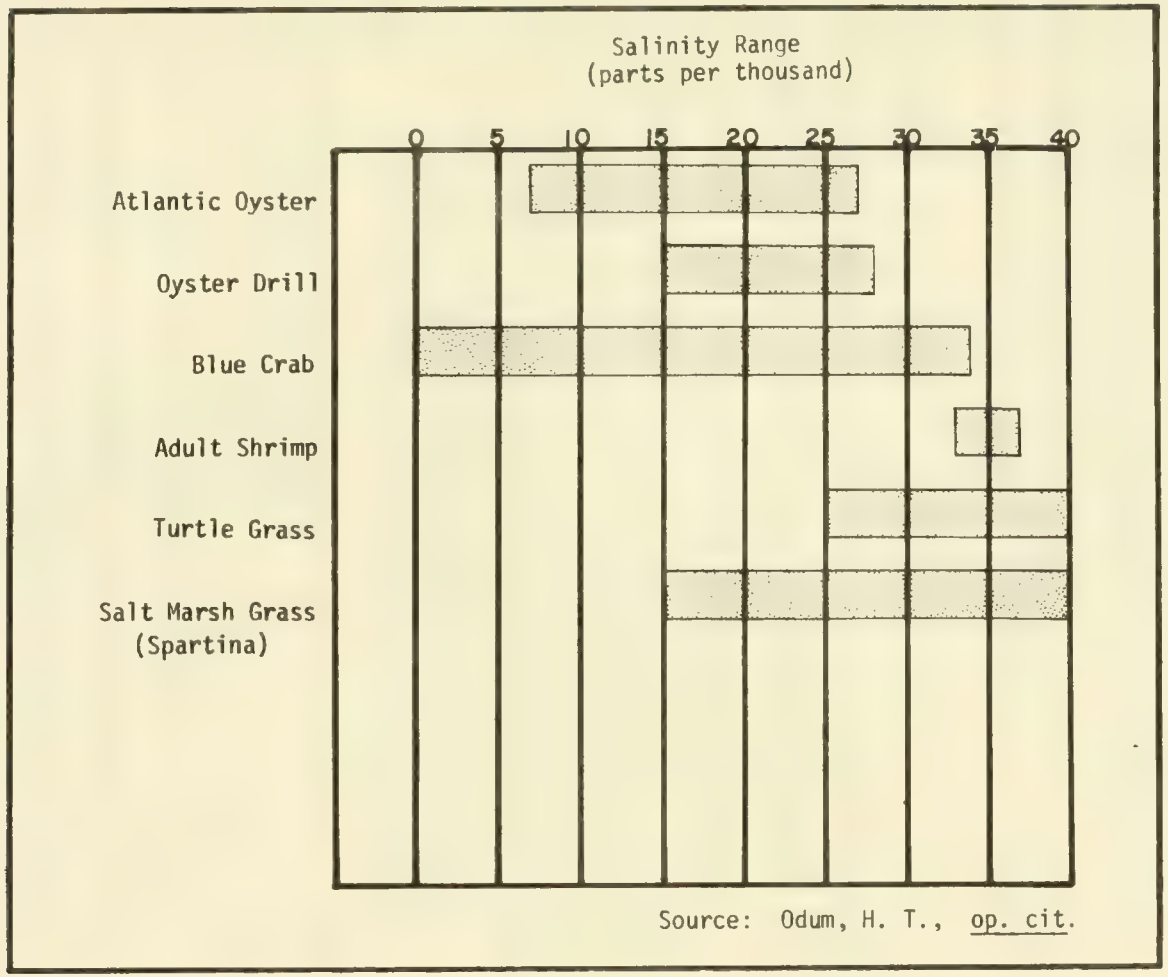
The ecosystems described relate primarily to organisms that tend to stay in one place or move only short distances during their life. Of these, the oyster, the clam, the crab, and the lobster are the only economically significant animals. The great importance of such ecosystems, however, lies in the fact that these communities form intermediate steps in the conversion of solar and gravitational energy to forms useful to mankind; upon them depend the great pelagic fisheries which the estuarine zone nurtures. Without these communities mankind would be without shrimp, salmon, and menhaden, as well as the oysters, crabs, and lobsters which spend all of their lives there.

The grouping of ecosystems outlined here describes a limited range of recurring variation of chemical and physical properties to which certain forms of life have adapted and on which they are now dependent. The basic environmental needs for all living plants and animals in such zones are zones of salinity consistently fluctuating over a limited range of concentration; solar energy; water temperature variation; water quality and nutrients favorable to their propagation, growth, and survival; and, for some life forms, bottom conditions suitable to their unique needs.

Many forms of plant and animal life can tolerate salinity ranging from ocean concentrations (35 parts per thousand) to practically zero. Other life forms must have a much narrower salinity range in which to live and reproduce. There are animals which require different salinities at different parts of their life cycle and which migrate to find it. Figure IV.1.36 shows the range of salinity tolerance of some characteristic estuarine plants and animals. Most of those with a limited salinity tolerance can also withstand temporary exposure to salinities outside that range.

Solar radiation governs the photosynthetic process by which plants manufacture the basic food upon which all life ultimately depends. The primary producers of food in the aquatic environment are the microscopic plants upon which the succession of more advanced life forms feed. Planktonic communities exist in all ranges of salinity and temperature, but their composition may vary even with constant

FIGURE IV.1.36 COMMON SALINITY RANGES OF OCCURENCE FOR SOME ESTUARINE-DEPENDENT PLANTS & ANIMALS



Source: Odum, H. T., op. cit.

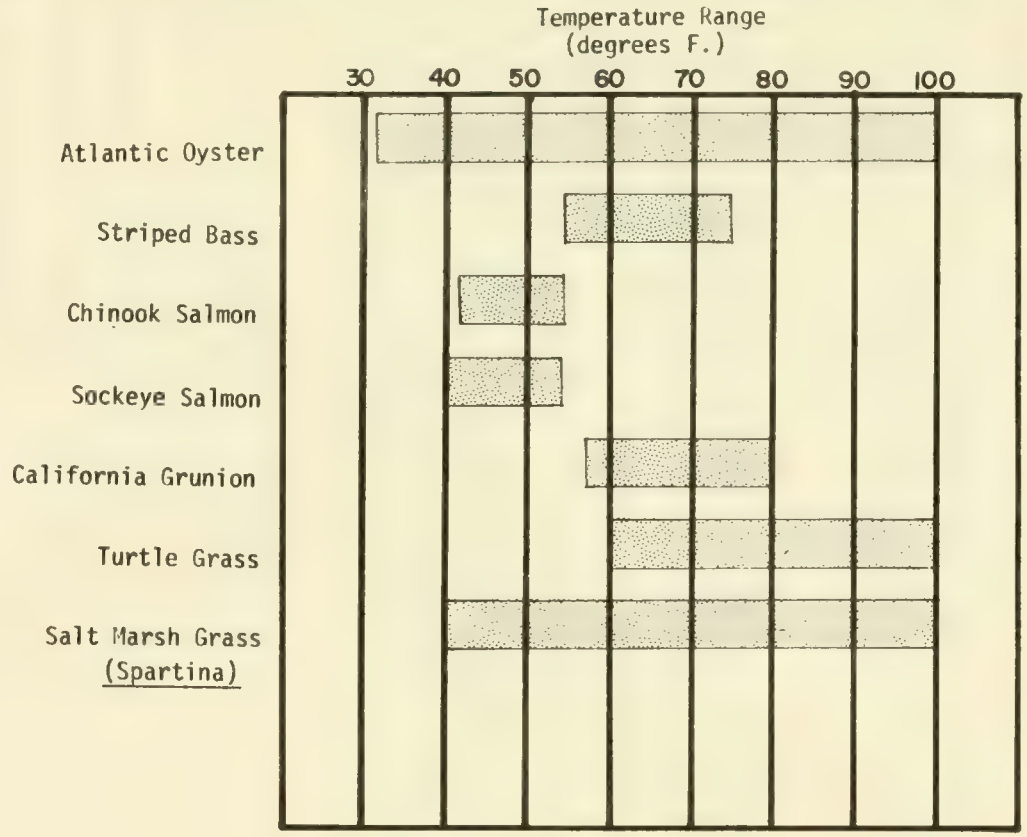
temperature and salinity. The rate of input of solar radiation is greater in the tropics than in the arctic, and life in tropical environments is more prolific than in the arctic.

Although water temperatures in the estuarine zone are closely related to the input of solar radiation, they are also greatly influenced by the temperatures of nearby cold or warm ocean currents. Many plant and animal species tolerate a wide enough temperature range to survive in considerable stretches of the estuarine zone from north to south.

There are a considerable number of plants and animals that have adapted to temperature ranges in the colder estuarine zone; others have adapted to temperature ranges occurring in the warmer temperate and sub-tropic waters of the estuarine zone; and there are some that have adpated to the colder waters of the northern estuaries, the warmer waters of the southern estuarine zone, and the gradations in between. Figure IV.1.37 shows the temperature ranges tolerated by some characteristic estuarine organisms.

The quality of water in the estuarine zone has sometimes dramatic, sometimes subtle, effects on estuarine life. The dissolved and particulate nutrients so plentiful in the coastal zone make this area very productive compared to other parts of man's environment. The coral reef communities of the tropics, where energy conversion is primarily a matter of photosynthesis, are nowhere near as productive as the oyster reefs and marshlands of the temperate zone, where particulate organic foods as well as solar energy are converted into plant and animal tissue for use by animals higher in the food chain.

FIGURE IV.1.37 COMMON TEMPERATURE RANGES OF OCCURENCE OF SOME ESTUARINE-DEPENDENT PLANTS & ANIMALS



Sources: Odum, H. T., op. cit.
"Industrial Waste Guide on Thermal Pollution," FWPCA, p. 40-42 (1968)

DEPENDENCE OF FISH AND SHELLFISH ON THE ESTUARINE ZONE

Dependency is governed by particular environmental requirements for reproduction, protection, food supply, or a combination of these. Estuarine dependent species are of three types:

(1) Species Restricted to Estuaries

Among the relatively few species of fish and shellfish that complete their entire life cycle in the estuarine zone is the Atlantic oyster. It will die after long exposure to freshwater although it can stand limited periods of such exposure and can thrive in relatively high salinity water. The spotted sea trout occupies the estuary for all its life purposes and only occasionally leaves the estuary under unusual extremes of salinity and temperature.

(2) Anadromous and Catadromous Species

Anadromous species pass through the estuarine zone on their journey from the sea to the freshwater environment where they spawn. Some species, such as the Pacific salmon, die after spawning and others, such as the striped bass, live to return to the estuarine zone and the sea. The young of all anadromous species spend varying periods of time in the freshwater areas where they were spawned, but all eventually migrate to the estuaries and then the sea.

There are few truly catadromous species that mature in the fresh or brackish water environments, and then migrate

to higher salinity waters of the estuary of the adjacent sea to spawn. The American eel and the Blue crab are examples of this type.

(3) Migratory Estuarine Species

The great majority of estuarine dependent species fall under this classification. Some use the brackish and freshwater areas of the estuarine zone for reproduction; some as a source of food; some for shelter, either as adults or young; and some for all these reasons. They all have in common the basic need for both estuarine and ocean environments at some point in their life cycle. This group includes the great majority of fish and shellfish of direct importance to man, such as shrimp, menhaden, flounders, and red drum.

Various types of dependency are illustrated by several examples.

SHRIMP

The commercially important shrimp are of three kinds: brown, white, and pink. These species are concentrated along the South Atlantic and Gulf coasts of the United States. The pink shrimp spawns in offshore waters at depths of 100 to 150 feet, salinity between 3.61 and 3.77 percent, and temperatures between 64 and 77^{o}F. After 13 or 14 hours, the eggs hatch and the larval shrimp begin to pass through a series of developmental stages, at the same time beginning to move or drift towards the Florida mainland about 100 miles distant (Figure IV.7.38).

Figure IV.I.38

TYPICAL LIFE HISTORY OF THE GULF OF MEXICO SHRIMP

Source: W.C. Guest, The Texas Shrimp Fishery, 1958.

a Shrimp Eggs	d Mysis	g Adolescent Shrimp
b Nauplius Larva	e Postmysis	h Adult Shrimp
c Protozoa	f Juvenile Shrimp	

Movement to the estuary probably takes from three to five weeks and, despite the large numbers of postlarvae entering the estuary, only an estimated five out of every hundred eggs produce shrimp that survive to this stage.

By the time the estuary is entered, the postlarvae have developed from planktonic to benthic feeders and have developed a wide tolerance to varying salinity and temperature conditions. From about two to nine months the juvenile shrimp grow rapidly from perhaps one-half inch in length to commercial size before returning to the sea and completing the life cycle.

The life cycle of the three primary commercial species are similar but the species differ in their penetration of the estuary and their utilization of the estuarine environment after the adult stage is attained. The brown shrimp spawns in waters 150 to 230 feet in depth and remains a relatively short time in the estuary. The white shrimp rarely is found in waters deeper than 100 feet and p ssesses a greater affinity for fresh water than do the others.

The estuary fulfills two primary functions: (1) provision of adequate nourishment during a period of rapid physical growth and (2) protection from predators. A large proportion of the shrimp's diet appears to consist of small, invertebrate animals, such as worms, mollusk larvae, and small crustaceans, as well as fish larvae and nematodes.

Shrimp is a primary food item for various estuarine animals, including red drum, spotted seatrout, snook, and gray snapper; but the estuary undoubtedly provides more vegetation and debris for protection than open waters, and sufficient alternative foods exist in the estuaries to remove some of the pressure from the shrimp.

MENHADEN

Spawning occurs at sea along the continental shelf, and the eggs hatch in the ocean after about two days. Larvae move into the estuaries as far as the freshwater interface. A transformation of physical characteristics accompanies the entrance into the estuaries as larvae grow and shift from being selective, particulate feeders to being non-selective, filter-feeding juvenile menhaden which can tolerate wide variations in both salinity and temperature.

The menhaden population of a particular estuarine system seems to be determined by the number of larvae entering the waters, food, oxygen, competition, and predators. Because they are primary consumers, feeding directly upon the natural vegetation, menhaden represent the base of the food chain for many predators, such as the bluefish, striped bass, and sharks.

SALMON

There are today only token runs of Atlantic salmon into a few rivers in Maine to spawn, although in colonial times this species was extremely abundant from the Housatonic River to the St. Croix River.

In the shallow estuarine areas of the Bay of Fundy and the coastal bays and sounds of Maine they are frequently caught in herring weirs set in shallow water. The waters in these estuaries provide an abundance of food for the salmon in the form of the young sea herring and euphausiid shrimp.

All five species of salmon on the west coast have one basic difference from the Atlantic salmon. They die subsequent to spawning. The total spawning range of these species is from Monterey Bay, Calif., to the northwest tip of Alaska. Only the King salmon occupies the spawning streams of the full range. The Silver salmon has the next longest range along the coast extending from the Sacramento River to the Bering Strait. The Red, Pink, and Chum salmon range from Washington State to the Bering Sea, and are rarely found south of this.

The distance upstream that the Pacific salmon migrates to spawn varies from species to species, as well as within species, varying from the extreme headwaters 1,500 miles from the estuarine zone to within a few miles of the estuary. Both the young and adult salmon of all species pass through the estuarine zone, either to reach the spawning ground in fresh water or to reach the sea. During the passage through the brackish estuary the adult ceases feeding, whereas the young of all species utilize the food available in the estuarine zone as they pass through to reach the sea. Young Silver salmon are known to remain within the estuarine portions of their natal stream, growing

rapidly on the abundant food supply in this highly productive environment. Adult Silver salmon are caught throughout the year within the estuarine zone. The Pink salmon fry enter the brackish estuarine waters soon after hatching in the Spring, and are known to remain there until August.

OYSTERS

The Atlantic oyster has evolved into an animal of broad adaptability relative to salinity, temperature, and food requirements, as indicated by its range, on the Atlantic and Gulf coasts of North America from the Gulf of St. Lawrence to the Mexican coast.

The Atlantic oyster is most abundant in estuarine systems characterized by considerable inflows of freshwater, with constant water movement, and fluctuating local salinities. The currents bring food to these fixed animals and distribute the larvae. Two of the most productive areas for the Atlantic oyster are the Chesapeake Bay and the Louisiana bays and sounds affected by the great flow of the Mississippi River.

The salinity range most favorable to the Atlantic oyster lies between five and thirty parts per thousand. Below five little or no reproduction takes place and the feeding ability is affected. Oysters occupying areas with salinities exceeding fifteen parts per thousand are subject to a number of predators such as the oyster drill.

The Atlantic oyster has adapted to wide ranges of temperatures. It survives in temperatures of around 34°F. and in temperatures of up

to 90°F. Intertidal oysters in the warm climate of Texas survive a number of hours out of the water with internal temperatures of as much as 120°F. This oyster ceases feeding when temperatures fall below 43°F. or rise above 107°F. Oysters spawn only when the temperature of the water rises above 68°F., whether in Long Island Sound or Apalachicola Bay. In its southern range the oyster has a much longer spawning period and feeds all year long.

SECTION 6. ENERGY AND MANAGEMENT IN THE BIOPHYSICAL ENVIRONMENT

Solar energy and gravitational energy are the basis for everything that happens naturally in the estuarine zone. This discussion of the biophysical environment has been concerned primarily with the transformation of these energies into forms useful in living processes and exploitable by man. Three different sets of subdivisions of the biophysical environment were used in this discussion (Figure IV.1.39).

Differences in the external environment divide the estuarine zone of the United States naturally into ten geographic regions, each subject to a particular combination of the external influences of tide, ocean currents, wave action, sedimentation, and climate. This subdivision into estuarine biophysical regions gave broad ranges of conditions in each region, but the importance of local coastal conditions in determining energy flows via water movement paved the way for a subdivision of the estuarine zone according to 11 morphological groups having similarities in water movement, circulation, and the ability to rid themselves of wastes.

A subdivision according to ecological communities is also based primarily on geographical location, but again local coastal conditions make it necessary to identify small ecosystems within each major grouping. This subdivision rests not only on the shape and form of coastal areas, but also on the composition of the estuarine bottom.

As an illustration of the relationships of these groupings, consider the ways to classify a group composed of all the deliverymen in the United States. They work in 50 States (the biophysical regions); they work in cities, towns, and rural areas (the morphological classification); they deliver different kinds of things, such as groceries, clothes, furniture, and hardware (the ecosystems).

Each of these different groupings of the estuarine zones is significant to management. The biophysical regions are contiguous geographic zones with similar general environmental conditions that would be appropriate for an institutional management unit. The morphological grouping can serve as a guide to useful physical modification and necessary waste treatment, while the ecological grouping tells what can and can't be done with the living resource.

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IV-1-1 The material presented in this chapter was distilled from a number of sources. While individual citations are given in some cases, the complexity of the source information precludes detailed references. The more informative general references are these:

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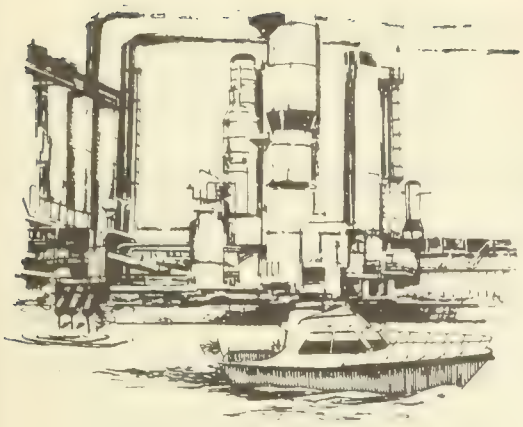
Chapter 2

USE OF THE ESTUARINE ZONE



The predominant uses of any particular estuarine area depend on historical and economic development, population pressures, and the kinds of natural resources available for exploitation. The socio-economic environment of the estuarine zone is the direct result of the value of the estuarine zone as a means of sustenance, a place to live and work, a source of enjoyment, and a means of transportation. This chapter describes that environment in terms of how the biophysical environment is exploited to serve man's needs and shows conceptually how valuable it is to his society (IV-2-1).

The major values of the estuarine zone to society from the framework for discussing the relationships of individual uses, their compatibility with other uses, and the physical modification that has taken place to support these uses.

SECTION 1. SUSTENANCE: USE AS A FISH AND WILDLIFE HABITAT

FISH

Estuarine dependence is a convenient term for describing a normally complex biological interrelationship between the estuarine environment and an aquatic organism. This dependence includes a vast spectrum of biological relationships. Practically all of the sports fish species are dependent upon the estuarine zone for one or more phases of their life development, and approximately 65 per cent of all commercial fish species are estuarine-dependent. The discussion in Chapter 1 concerning life in the estuarine zone described the nature of estuarine dependence and gave examples of several estuarine-dependent species important to human society.

Many fish species live their entire lives in the estuarine zone and are well-adapted to this type of environment. The oyster, for example, has lived in the estuary for millions of years, as evidenced by the huge deposits of shell on the bottoms of bays. The shallow water, salty substrate, and intermediate salinities are ideal for oyster culture.

Other species may use the estuary only as a passage zone on their way to freshwater streams or to the open ocean. However, in doing so, they also utilize the high production of food that is

characteristic of estuaries. Even some continental shelf species, such as bluefish, and most marine predators (including tuna), can be considered dependent upon the estuary as an ultimate source of most of their food.

The economically important fish species are those sought by either the sports fisherman or the commercial fisherman; however, the sports fishes are usually taken by hook or with hand-held equipment. Table IV.2.1 lists some of the more important estuarine-dependent species of sports and commercial fish and shellfish. It also shows the type of dependency of each.

Figure IV.2.1 illustrates the geographic ranges of some of the estuarine-dependent sport and commercial fish throughout the United States, and many of these different kinds of sports fish can be caught as one goes from salt water to fresh water within an estuary (Figure IV.2.2). Fishermen have nearly as much variety as the fish they catch, as Figure IV.2.3 demonstrates. Even the ocean fisheries are to some extent related to the estuarine zone, because most fishing and the most productive fishing grounds are close to continents. Latitudinal ranges of some major commercial fish off United States coasts are shown in Figure IV.2.4.

TABLE IV.2.1

Estuarine Dependence of Important Sport and Commercial Fish

Biophysical Region	SPORTS FISH: TYPE OF DEPENDENCE		
	Permanent Residence	Passage Zone	Nursery Zone
North Atlantic	Croaker Atlantic Mackerel Bluefish	Atlantic Salmon Shad	Striped Bass
Middle Atlantic	Croaker Drums Atlantic Mackerel Spot Bluefish	Shad	Striped Bass
Chesapeake	Crabs Croaker Drums Spot Bluefish	Shad	Striped Bass
South Atlantic	Crabs Croaker Drums Spotted Sea Trout Spot Bluefish	Shad	Striped Bass
Caribbean	Spotted Sea Trout Spot Bluefish		
Gulf of Mexico	Crabs Croaker Drums Spotted Sea Trout Spot Bluefish	Shad	Striped Bass
Pacific Southwest	Abalone Rockfish Barracuda		
Pacific Northwest	Abalone Rockfish	Salmon (Chum, Coho, King, Red)	Pink Salmon
Alaska	Crabs	Salmon (Chum, Coho, King, Red)	Pink Salmon
Pacific Islands	Barracuda		

TABLE IV.2.1--(Cont'd.)

Estuarine Dependence of Important Sport and Commercial Fish

Biophysical Region	COMMERCIAL FISH: TYPE OF DEPENDENCE		
	Permanent Residence	Passage Zone	Nursery Zone
North Atlantic	Oysters Clams Croaker Flatfish	Atlantic Salmon Eel	Menhaden Lobsters
Middle Atlantic	Oysters Clams Croaker Flatfish	Eel	Menhaden
Chesapeake	Oysters Flatfish Clams Crabs Croaker	Eel	Menhaden
South Atlantic	Oysters Crabs Croaker Flatfish	Eel	Shrimp Menhaden
Caribbean	Flatfish		Lobsters
Gulf of Mexico	Oysters Crabs Croaker Flatfish		Shrimp Menhaden
Pacific Southwest	Clams Abalone Flatfish		
Pacific Northwest	Oysters Abalone Crabs Flatfish	Salmon (Chum, Coho, King, Red)	Pink Salmon
Alaska	Crabs Flatfish	Salmon, (Chum, Coho, King, Red)	Shrimp Pink Salmon
Pacific Islands	Oysters Flatfish		Lobsters

FIGURE IV.2.1 SPORTS FISH OF IMPORTANCE TO ESTUARINE FISHERMEN* **

*Generally, distributed latudinally that is similar species are found on both coasts usually by different names

**Ranges of all types vary widely

SOURCES 1965 Salt Water Angling Survey BSF&W
Fishery Statistics of the United States BCF

FIGURE IV.2.3.a A YOUNG SALT-WATER FISHERMAN GETS HIS START IN THE BAYOUS OF LOUISIANA

COURTESY LOUISIANA WILD LIFE AND FISHERIES COMM. PHOTO BY J. H. BRITT

FIGURE IV.2.3b

TRY YOUR FISHING FROM A BEACH IN FLORIDA
FISHING TARPON FROM A SMALLCRAFT
THE "COMPLEAT ANGLERS" IN A MARSH
TRY YOUR LUCK WITH A NET

FIGURE IV.2.4. LATITUDE RANGES OF SOME COMMERCIAL FISH*

*RANGES VARY IN SOME CASES ACCORDING TO SEASON OF YEAR OR OTHER FACTORS.

WILDLIFE

Estuarine wildlife can be classified into four categories with differing economic significance: (1) fur bearing mammals, (2) game waterfowl, (3) ornamental shore birds, and (4) the common wildlife that can tolerate human presence. The relative abundance of some characteristic species in the biophysical regions is discussed below.

Fur Bearers

The primary estuarine fur bearers are the fur seal in Alaska, nutria in the South Atlantic and Gulf States, the common eastern muskrat in New Jersey, the Virginia muskrat in the Central Atlantic States, and the Louisiana muskrat in Alabama, Mississippi, Louisiana, and Texas. Secondary in importance are the raccoon, mink, and otter. Foxes, weasels, opossum, and bobcats are not sought for their fur but may occasionally be trapped (Figure IV. 2.5).

For economic levels of fur production, the marshes must be managed specifically for the fur bearers. This means control of undesirable plants, prevention of excessive populations and, in some cases, control of predators. The primary food plants are threesquare and cattails; these, however, are easily supplanted

by invading needleruch, cordgrass, sawgrass, and other undesirable plants. Hence, the marshes are burned annually, usually in the fall, and are subsequently flooded to eradicate the pest plants and enhance growth of threesquare (Figure IV.2.6). Dikes or other water control devices are used to help minimize the intrusion of salt water into the fresh or brackish water of the producing marshes. Thus, the marshes managed for fur production are not normally available for other valuable aquatic species, especially shrimp and estuarine-dependent fish (Figure IV.2.7).

Game Waterfowl

The dependence of waterfowl on the estuarine zone is both complex and not completely understood. The primary sport species, such as mallards and canvasbacks, have been successfully adapted to man-made changes in their environment, particularly those which do not affect the nesting sites. In some cases, the construction of roads, drainage canals, and other works have enhanced nesting areas by stabilizing water levels, providing flood-proof nesting sites and drought-proof rearing ponds. Furthermore, most species do not appear particularly dependent on any aspect of the estuarine zone, being able to use freshwater marshes, lakes, and ponds with equal ease. This ambivalence has been sharply enhanced in the Gulf area by extensive rice cultivation and cattle farming

which enable many species, such as the white-fronted geese, to shift habitats away from estuarine marshes. Other species, such as Canada geese and mallards, have demonstrated even more adaptibility, many remaining the entire winter in the freshwater bodies of the Midwest (Figure IV.2.8). Many sea ducks feed upon small crustaceans, fish, and insects that are estuarine-dependent. These ducks have not learned to feed on agricultural lands, and tend to migrate to deeper saltwater environments during the winter.

In summary, while game waterfowl are frequently observed in the estuarine areas, they do not appear dependent upon specific estuarine conditions. There are some exceptions, such as the American brant, but research has not determined the relationship between altered habitat and declining numbers.

Ornamental Birds

Shore and sea birds are a particularly aesthetic attraction among the national fauna. However, they rarely have a direct tangible economic value, except as a component of the natural ecosystem. These birds are generally more dependent upon estuarine conditions than the more mobile waterfowl, and have demonstrated a greater sensitivity to the overall encroachment of man. The saga of the virtually extinct whooping crane is well known and documented;

and the trials of several other groups, such as the egrets, have received periodic publicity. Among the bird life most threatened by changing environmental conditions, especially in the estuaries, are the larger fish-eaters of the Nation's coast.

The brown pelican has already disappeared from the Gulf coast of Alabama, Mississippi, Louisiana, and Texas, where it was a common sight prior to 1960. This disappearance coincided with the heavy fish kills of 1960-1964 in the Lower Mississippi River, which were caused by excessive residues of pesticides. One theory proposed that the dead and dying pelicans observed during that period had accumulated lethal dosages (Figures IV.2.9). This assumption, however, was not verified and another theory used to explain the lack of any recovery was the destruction of nesting grounds in black mangroves by the severe cold.

The 80 species of waders, which include the egrets, storks, herons, ibis, and spoonbills, are predominantly residents of the southern United States, particularly in Florida. The recent drought and man-made changes in the Everglades have drastically reduced the number of these species in Florida. For some species, this represents a serious setback in their gradual recovery from near extinction at the hands of the plume hunters. Waders elsewhere on the southern coast have also diminished in numbers, apparently because of irresponsible shooting and man-made environmental changes.

FIGURE IV.2.9.

ONE LESS BROWN PELICAN IN THE SOUTHEAST.

ONE OF OUR MORE SERIOUSLY THREATENED SPECIES AFFECTED BY DDT.

AQUACULTURE

The great fish and shellfish resources of United States coastal waters have adequately supplied the seafood demands of the increasing population for over three hundred years. Now, however, the demand for some products is so large that the normal fishing grounds and fisheries are in great danger of being exhausted, both from overfishing and from the indirect effects of man's encroachment into the estuarine environment. To supply future needs of some fish products new approaches toward commercial fishing are needed, both in harvesting the natural growth and in controlling the entire fishery.

Aquaculture is defined as the rearing of aquatic organisms, both plants and animals, under controlled conditions using the techniques of plant and animal husbandry. It involves a variety of operations: some are highly sophisticated where man exercises control over the principal environmental factors affecting the cultured species, and others are very simple with only minimal control or manipulation of the habitat and the cultured animal.

The following examples illustrate the variety of aquacultural activities that are now practiced:

(1) Rearing aquatic species from selectively bred strains to commercial size under controlled conditions where the optimum requirements for food, temperature, salinity, and other physiological and environmental needs are provided; predators and competitors are eliminated and diseases controlled, and highly mechanized methods are used to reduce labor costs. This is the ultimate in aquacultural operations and has been achieved only for a few species (e.g., carp).

(2) Rearing aquatic species in natural or artificial enclosures to commercial size, with or without supplemental feeding, predator control, environmental adjustment, and selective breeding. Enclosures may be man-made tanks, natural or artificial ponds, or enclosed areas of the sea. Such techniques are now used for the production of oysters, clams, shrimp, catfish, carp, and baitfish. (Figure IV.2.10).

(3) Rearing aquatic species in hatcheries through the juvenile stages, the period of greatest natural mortality, to stock natural areas. This effort may be used to replenish stock reduced by natural or artificial changes in the environment, overfishing or other factors, or to introduce new species into an environment. Such methods are being used to maintain salmon and trout fisheries and to provide sport fish in areas of heavy fishing pressure.

(4) Transplanting wild stocks as eggs, young, or spawning adults from one natural area to another to provide more suitable habitat for spawning, growth, or survival, and to introduce species into new environments. This method has been the backbone of present day oyster culture on leased grounds. This method was also used to introduce striped bass and shad from the east coast to west coast waters. Widespread transplants of salmon have also been made with varying success.

(5) A variety of other techniques have been developed to increase abundance and survival of commercially valuable species, e.g., cultching oyster beds with shell to increase setting; suspending shell strings from floats or piling to catch larval oysters and grow the adults using the total water column (Figure IV.2.11); moving oysters to predator or disease-free areas; construction of artificial reefs to provide more suitable habitat for oysters, lobsters, and fish (Figure IV.2.12); and opening or closing breaches in barrier islands to improve environmental conditions of essential lagoons.

(6) Aquaculture is also practiced in the experimental rearing of larval fish and shellfish to study the importance of environmental factors on survival and to determine causes of the marked variation in year-class size.

Aquaculture, with a few minor exceptions, appears to be today where agriculture was fifty or more years ago. True farming of the sea is still in its infancy. At the present time almost all of the oysters produced on the west coast of the U.S. have at least one manipulation by man before they are harvested; on the Atlantic seaboard approximately fifty per cent are manipulated at least once before harvest. Other than oysters, there are no known enterprises in marine aquaculture that are expecting a significant profit. Many ventures are presently underway to develop pilot plants for commercial farming in the future.

Table IV.2.2 lists the range of species that are presently being studied for marine aquaculture. Research is at private, university, State government, and Federal Government laboratories.

TABLE IV.2.2
Species Under Marine Aquaculture Research

Organism	State
Algae	Fla.
Shrimp	Ala., Fla., Tex., La., S.C., Calif.
Crabs	Calif., Md., Ore.
Lobsters	Me., Fla., Calif., Mass.
Crayfish	La.
Freshwater Shrimp	Fla., Ala., Haw.
Mussel	Calif., Ore.
Oyster	N.C., Del., Va., Conn., N.Y., Calif., Tex., La., Ala., Miss., Mass., Wash., Ore., R.I., Fla., Ga.
Scallops	N.Y., Fla.
Clam	N.Y., Ore.
Marine Worms	Me., Fla.
Alligators	La.
Freshwater Catfish (brackish water)	La.
Spot	La.
Croaker	La.
Mullet	La., Haw.
Pompano	Fla., La., Tex., S.C., Ala.
Sea Trout	Fla.
Abalone	Ore., Calif.

SECTION 2. ENJOYMENT: USE FOR RECREATION

The demand for outdoor recreation has increased significantly over the past decade. The trend toward higher personal income and more leisure time has made it possible for a greater percentage of the populace to seek new outlets. The advertising industry has campaigned vigorously to sell the public on the need for recreation. Companies manufacturing equipment for outdoor recreation, and service facilities to support the "recreationalist" are blossoming in all parts of the country. In addition, the unique availability of resources, in close proximity to large population centers, offers an unparalleled recreational opportunity for many who previously could not afford to travel far from their homes.

Since there is this wide variety of land and water recreational activities available in the estuarine zone, many estuarine systems are intensively used for these pursuits. This is primarily because people rarely have a single activity as the sole objective of a recreational outing. Clusters of activities that require similar environmental conditions, but differ in environmental quality needs, can be grouped as follows: 1) Swimming and associated shore activities, which include picnicing and camping; 2) sports fishing from the shore or a small boat; 3) boating which is one of the most popular water-based activities, and boat-centered activities, such as fishing, water skiing,

cruising, hunting, and even traveling or socializing; and 4) aesthetic appreciation of the total environment.

Based on attendance, the most heavily used beaches in the United States are Long Island in New York and the coastal beaches of Maryland, Virginia, Massachusetts, Florida, and California. The majority of these beaches face the open sea rather than an estuary or coastal sound. It is estimated that less than 10 per cent of the entire coastal swimming activity, or less than 3 per cent of all swimming participation, occurs inside embayments. This apparent lack of utilization of swimming is based on several factors varying from personal preference to environmental quality. The most significant reasons are these:

(1) There is a lack of large sandy beaches, surf, and expansive seascapes.

(2) Public access is limited bacause of marshy terrain and private development along the shoreline. (For example, of all Maryland's 41 State parks, including those authorized or under construction, only five are on the estuaries. In Connecticut only five of the 82 State parks are located on the coast, despite a recreation shoreline of 162 Miles).

(3) Swimming is often prohibited or is disagreeable in embayments because of low water quality.

The fishing aspects have been discussed previously, but are mentioned again because of the relationship between sport fishing and recreation, especially as an associated activity. Pleasure boating and shoreline activities are frequently extensions of sport fishing trips or vice versa.

Boating is a major recreational use of the estuarine system. On a per capita basis however, the coastal States do not have a high propensity towards boating activities. While representing 61.5 per cent of the Nation's population in 1966, the coastal States accounted for only 55.4 per cent of the total sales in outboard motors. Only about 25 per cent of all pleasure boating is estimated to occur in the coastal waters, most of which is in protected areas.

Aesthetic enjoyment is probably the most widespread use of the estuarine environment today. Tourists from the interior States are always eager to view such sights as ships coming under the Golden Gate Bridge into San Francisco Bay, the lonely solitude of Fort Sumter as it rests seemingly impregnable in Charleston Harbor, and the parade of ships in and out of New York Harbor. The attractive scenic vistas are not for the tourists alone, but hold a certain magnetism for residents of the coastal cities as well. One has only to scan the real estate advertisements to realize the premium value on waterfront or waterview lots.

Many of the coastal cities have had the foresight to reserve the estuarine shoreline for parks and scenic parkways. The George Washington Memorial Parkway in Virginia is a good example, for it allows unparalleled view of the historic Potomac River near the Nation's capital.

Aesthetic appreciation of the estuarine zone is not limited to the enjoyment of the scenic grandeur, but also includes observation of its wide variety of wildlife. This includes birds of all types, the fascinating creatures of the tide pools, and playful porpoises cavorting in the water with an enviable freedom.

A portion of the estuarine wildlife also serves another recreational use--hunting. Some of the estuarine marsh areas offer unexcelled waterfowl hunting opportunities. To a lesser degree the estuarine areas in certain sections of the country offer other types of hunting opportunities, such as coastal deer in South Carolina and Florida and big game in Alaska.

There are certain ancillary facilities and services necessary to realize the full potential of estuarine recreation. First and foremost is adequate access to the reserved areas such as parks, wildlife refuges, beaches and roadways, waterways, and paths. The Chesapeake Bay is an excellent example of a large estuarine system with limited public access: most of the access sites available to the public are privately controlled and charge user

fees.

Additional support services and facilities may range from nothing but access trails for wilderness areas to expensive resort type communities with shopping, hotel or motel accomodations, and restaurants.

The activity on which the recreation area is based generally determines the minimum support facility and service needs. Swimming requires, in addition to beach, sanitary facilities and life guards, as well as such items as food shops and beach equipment rental booths. If the beach is extremely popular, motels, specialty shops, and a whole spectrum of commercial enterprises will develop. If boating is the prime activity, launching ramps, marinas, and repair shops will be needed in addition to basic sanitary facilities. If fishing is the prime activity, bait and tackle shops are needed. It is evident that the extent of development of support service is almost unlimited, depending on the popularity of the recreational area (Figure IV.2.13).

Just how the popularity or importance of a particular recreational activity or area is measured presents another problem. Ideally, the importance could be defined as the sum of all the individual users' values. Since this figure is difficult if not impossible to obtain, some index of use must be developed. Table IV.2.3 shows some possible indices of use and some of their characteristics.

TABLE IV.2.3 INDICES OF RECREATIONAL USE OF ESTUARINE AREAS

INDEX FACTOR	ADVANTAGES	DISADVANTAGES
Number of Visitors	Direct indication of popularity	May have to be estimated; does not indicate type of activity. Difficult to evaluate economically.
Duck Stamps Sold	Readily available from records; Gives a partial dollar value.	Does not relate to estuarine area alone; not always an indicator of use.
Hunting Licenses Sold	Same as above	Same as above
Fishing Licenses Sold	Same as above	Many States do not require licenses for salt-water fishing.
Fishing Participation Days	An indicator of one specific type of recreational use; shows pressure on a particular area.	No records to furnish figures; No indicator of fisherman success. No monetary values attached.
Yacht Club Memberships	Records available to supply info.	May not be true indicator of participation in use. Applies to only a small segment of total user group.
Marina Slips	Info. readily available; indicates a capacity figure; gives indication ov value.	Not a true indicator of boating activity because of the mobility of transient boats.
Parking Area at Launching Ramps	Indicates estimated use importance of popularity.	Does not reflect actual use; no indication of number of people or size of boats or type of use.
Boat Registrations	Available from records.	Not all boats required to be registered. Trailer boats are extremely mobile & registrations do not show area of use.
Charter Boats Operating Including Tours & Passenger Space Available	May be indicative of potential traffic from given location or of desirability of an area for fishing or sightseeing.	Could be difficult to obtain. Does not reflect actual use, only capacity.
Non-Resident Hunting and Fishing Licenses	Information readily available from records. Indicates interest by out of state residents.	Not necessarily specific to estuarine zone; fishing licenses may not be required in salt water areas.

The relative intensity of recreational use of the estuarine zone varies in different sections of the country. Data pertaining specifically to the estuaries are not available; however, some information on the importance of recreation in the coastal area, which serves as an index to estuary potential, is given in Table IV.2.4. This table presents a breakdown of recreation shoreline by shore type, ownership, and degree of development. The recreation shoreline is defined according to accessibility and usefulness for recreational pursuits. It comprises about one-third of the entire tidal shoreline of the United States.

Analysis of the data in the table shows the differences in shoreline development in various sections of the country. The heavily populated northeast section of the country, including the North Atlantic and Middle Atlantic regions, has a fairly well-developed coastal area. Of the total 5,912 recreation shoreline miles (including the Great Lakes portion of New York) there are 5,654 miles under private or restricted public ownership, meaning that 97 per cent of the shore is inaccessible to the general public (Figure IV.2.14). In the Chesapeake and South Atlantic regions the state of shoreline development is low to moderate. Of the total 4,315 miles of recreation shoreline for the two regions, only 154 miles are public recreational areas, a mere 4 per cent of the total. The level of development of the Gulf coast is

TABLE IV.2.4 ESTIMATED MILEAGE OF THE UNITED STATES RECREATION SHORELINE (STATUTE MILES)

BIOPHYSICAL REGION	TOTAL SHORELINE	EXTENT OF DEVELOPMENT	TYPE OF SHORELINE			OWNERSHIP		
						PUBLIC		
			BEACH	BLUFF	MARSH	RECREATION AREAS	RESTRICTED AREAS	PRIVATELY OWNED
NORTH ATLANTIC	2,983	HIGH	159	2,683	142	43	3	2,937
MIDDLE ATLANTIC *	2,929	HIGH	742	1,146	1,041	147	66	2,717
CHESAPEAKE BAY	1,789	LOW	157	941	699	5	125	1,667
SOUTH ATLANTIC	2,517	MODERATE	746	283	1,489	149	72	2,295
CARIBBEAN (FLA.ONLY)	809	LOW	328	124	357	49	37	722
GULF OF MEXICO	3,542	LOW	1,247	586	1,809	81	94	3,469
PACIFIC SOUTHWEST	1,135	MODERATE	253	788	95	133	89	913
PACIFIC NORTHWEST	2,539	MODERATE	294	1,570	185	163	38	1,839
ALASKA		NO	DATA	AVAILABLE				
PACIFIC ISLANDS		NO	DATA	AVAILABLE				
TOTAL	17,353		3,915	8,121	5,817	770	524	16,559

* MIDDLE ATLANTIC REGION MILEAGES INCLUDE NEW YORK GREAT LAKES FRONTAGE AND EXCLUDES ALL PENNSYLVANIA FRONTAGE.

* REFERENCE: OUTDOOR RECREATION RESOURCES REVIEW COMMISSION, REPORT NO. 4

FIGURE IV.2.14. EXTENSIVE SHORELINE DEVELOPMENT ALONG A BAYOU IN LOUISIANA

PHOTO BY: ROBERT N. DENNIE, COURTESY OF LOUISIANA WILD LIFE AND FISHERIES COMMISSION.

relatively low. Out of a total 3,642 miles of recreation shoreline only 81 are dedicated to public recreational areas, a total of only about 2 per cent. The Pacific coast, which is composed of 75 per cent bluff type shoreline, in areas suitable for recreation provides 10 per cent of this length for recreation, or almost 300 out of 3,000 miles.

That so much of the recreation shoreline is in private ownership indicates the high value placed on waterfront property and the desire to own it, either for passive enjoyment or for more active recreational pursuits.

SECTION 3. USE FOR TRANSPORTATION

The Nation's estuaries provide the physical, social, and economic conditions required for an effective system of: water terminals serving international trade and coastal shipping; essential elements of the national defense system; areas used for airport development; and land transport.

According to a 1966 inventory of ports and terminals by the Maritime Administration, there were 1,626 marine terminal facilities providing deep water berths in 132 ports on the Atlantic, Gulf, and Pacific coasts. Table IV.2.5 shows the distribution of estuarine ports. The significance of these ports and terminal facilities is indicated by the 1965 statistics which show that they handled 78 per cent of the U.S. foreign trade total, or 346,315,000 tons of foreign trade cargo. In addition, the port facilities handled 332.1 million tons in coastal cargo and 288.2 million tons in local shipping.

Table IV.2.5 also shows arrivals and departures for the major U.S. ports for 1964. The traffic indicated by these statistics demonstrates the competition for water surface and navigation channels. In New York, for example, there are between two and three arrivals or departures every hour. Portland, the 11th ranking port in the estuarine zone, has an arrival or departure every two hours. There is very little information giving a breakdown in vessel

TABLE IV.2.5 ESTUARINE USE BY WATERBORNE COMMERCE, 1964

BIOPHYSICAL REGION	NUMBER OF PORTS	NUMBER OF TERMINALS	MAJOR PORT	COMBINED ARRIVALS & DEPARTURES	ESTIMATED #'S OF WATERCRAFT
NORTH ATLANTIC	10	10[illegible]	BOSTON	4,168	2,084
MIDDLE ATLANTIC	19	419	NEW YORK	24,580	12,290
			PHILADELPHIA	13,791	6,895
CHESAPEAKE BAY	5	157	HAMPTON ROADS	11,353	5,676
			BALTIMORE	10,734	5,367
SOUTH ATLANTIC	12	105	CHARLESTON		
			SAVANNAH		
			JACKSONVILLE		
CARIBBEAN	1	8	MIAMI		
			SAN JUAN		
GULF OF MEXICO	24	353	NEW ORLEANS	10,400	5,200
			HOUSTON	8,372	4,186
PACIFIC SOUTHWEST	19	222	LOS ANGELES-LONG BEACH	9,467	4,733
			SAN FRANCISCO	9,081	4,540
PACIFIC NORTHWEST	19	20[illegible]	SEATTLE	4,171	2,085
			PORTLAND	4,081	2,040
ALASKA	15	29	ANCHORAGE		
PACIFIC ISLANDS	9	41	HONOLULU		
TOTAL	133	1,634			

REFERENCE: THE NATIONAL ESTUARINE INVENTORY
DATA SOURCES: MARITIME ADMINISTRATION, U.S. ARMY CORPS OF ENGINEERS

types. Statistics for the year 1964 for the port of New York show 18,682 dry cargo or passenger arrivals and departures and 5,098 tankers.

The estuarine ports also serve as essential elements of the national defense system. The deep water terminals exert a significant influence on the location of defense installations, as well as of the industrial complexes necessary for logistical support of the defense effort. A direct indication of the use of estuaries by naval vessels is the total number of ships in commission. During the Fiscal Year 1967 this number was 931 with a planned increase to 960 in the Fiscal Year 1969.

In addition to those commissioned ships, in Fiscal Year 1967 there were 1,071 merchant ships in the National Defense Reserve Fleet. These ships are stored in the estuarine areas as shown in Table IV. 2.6.

TABLE IV.2.6
Fiscal Year 1967
National Defense Reserve Fleet (Merchant Ships)

Location	Ships Not Maintained	Ships Maintained In Retention Status	Total
Hudson River	69	68	137
James River	164	122	286
Mobile	65	100	165
Beaumont	25	100	125
Suisun Bay	99	128	227
Olympia	21	110	131
Total	443	628	1,071

Waterborne transportation in the estuaries is not a completely free gift. In all cases a large investment is required to support and sustain this activity. Adequate channels must be provided to carry the ship traffic. In almost all estuaries this involves maintenance dredging to provide sufficient water depth to float deep draft vessels (Figure IV.2.15). These channels must be marked with navigation aids to prevent the ships from inadvertently straying into shallow water. Terminal facilities are necessary for loading, unloading, and storing cargo. There must also by shipyards with all the equipment and facilities necessary to repair, maintain, and fuel the large ships (Figure IV.2.16).

Besides the physical facilities needed, there are certain environmental considerations. Already mentioned is sufficient water depth to keep the ships afloat. Since dock facilities and berthing space are expensive and cannot be monopolized for long periods of time by single ships, there must be safe anchorage areas where ships can await their turn at the piers. These anchorage areas also provide temporary safety during stormy weather and must, therefore, be sheltered from the direct force of the wind and waves. The whole concept of a harbor is a port of safety out of harm's way.

The advent of nuclear powered ships has presented additional problems. The harbor areas must be protected from every possibility of environmental contamination by radioactive substances, and these ships must have easy access to the sea.

The use of the harbors for waterborne transportation is competitive in that it may cause other uses to be foregone. Heavy ship traffic interferes with pleasure boating and related activities (Figure IV. 2.17). Maintenance of the ship channels may alter the ecology and the surface area occupied by the large vessels may well interfere with safe pleasure boating.

Transportation in estuaries is not limited to waterborne traffic. Since a major percentage of large cities are located on estuarine systems, there is considerable pressure to develop fill areas for airports which then utilize the long overwater approaches to keep the jet noise away from developed areas. San Francisco International Airport is a good example, and in Washington, D.C., National Airport uses fill areas and overwater approaches (Figure IV.2.18).

As the airplanes get bigger and the air traffic gets heavier, it appears that more cities will try to develop isolated airport facilities. The planning of the Miami Jetport in the Big Cypress Swamp is a good example. In cities where estuarine areas are available a similar trend will probably develop. The last aspect of trans-

portation to be considered is that of land transport. A dichotomy exists here. The water areas offer a barrier to land travel that must be overcome with causeways or bridge type structures which can interfere with navigation or cause habitat damage. On the other hand, peripheral roads offer some of the more scenic routes available and are frequently the only undeveloped area on which roads can be built. Examples of these peripheral roads are Bayshore Drive in Tampa, Florida; Bayshore Freeway south of San Francisco; and Harbor Drive in San Diego (Figure IV.2.19).

SECTION 4. USE AS A HUMAN HABITAT

These are the uses that occur wherever people live and work in civilized communities. They represent uses not unique to coastal areas, although the estuarine zone places restrictions on some uses and offers advantages in other activities.

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

The water in the estuary can serve as a source of both domestic and industrial water supply, but its utilization for domestic supply is very limited at the present time. Normally the brackish water is unpotable and treatment costs to render it potable are extremely high; however, where the upstream freshwater inflow is sufficient to repel salinity intrusion from portions of the tidal area, the water is used for a domestic and agricultural water supply source. The San Francisco Bay Delta area is an excellent example of this, although there are few others.

The brackish estuarine water is also a poor source for industrial process water. Here again a high degree of purity is normally required in the process water and the cost of removing the dissolved salts is prohibitive.

Estuarine waters are used extensively, however, as a source of industrial cooling water. For this use the most important considerations are ambient temperature and quantity. Water temperatures are generally

well below the maximum for economical cooling, and since the ocean is connected to one side of the estuary, the quantity is no problem. Cooling water is required by both the manufacturing industry and electric power generation plants; the greatest use is in the thermal electric plants. Table IV.2.7 shows cooling water withdrawals in the coastal counties. Not all of the amounts shown are taken from estuarine waters, but almost all of these quantities find their way back into estuarine waters.

The distribution of cooling water uses parallels population and industrial development in the coastal counties, even though electrical power can be transported economically over many miles. The greatest concentrations of cooling water use are in the Middle Atlantic and Pacific Southwest regions; these regions both have moderate water temperatures which make possible efficient use of the available cooling water.

Table IV.2.7 also shows, however, that there are 47 nuclear power plants built or scheduled for completion by 1976. All of these are in the megawatt range, with a combined capacity of nearly 35,000 megawatts of electrical power. While the bulk of these will be in the cooler parts of the Nation, 12 will be in the South Atlantic, Gulf, and Caribbean regions. In these regions water temperatures are high, greater volumes must be used to achieve proper cooling, and the increase in water temperature through the power plant may be sufficient to cause environmental damage.

TABLE IV.2.7 ESTIMATED COOLING WATER USE IN THE COASTAL COUNTIES, 1963

BIOPHYSICAL REGION	TOTAL COOLING WATER USE (MILLION GALLONS PER DAY)	POWER GENERATING PLANT USE	MANUFAC-TURING INDUSTRIAL USE	EXISTING OR PLANNED NUCLEAR POWER PLANTS (#)
NORTH ATLANTIC	1,480	1,200	280	3
MIDDLE ATLANTIC	11,030	9,000	2,030	20
CHESAPEAKE BAY	1,040	850	190	5
SOUTH ATLANTIC	350	290	60	8
CARIBBEAN	330	270	60	3
GULF OF MEXICO	1,020	830	190	1
PACIFIC SOUTHWEST	3,850	3,150	700	5
PACIFIC NORTHWEST	900	730	170	2
ALASKA	NO DATA	NO DATA	NO DATA	NO DATA
PACIFIC ISLANDS	100	80	20	NO DATA
TOTAL ESTUARINE ZONE	20,100	16,400	3,700	47

REFERENCE: U.S.DEPT. OF COMMERCE, BUREAU OF THE CENSUS, CENSUS OF MANUFACTERS, 1963
NATIONAL ESTUARINE INVENTORY

In addition to water temperature, there are other environmental requirements and problems associated with the use of estuarine waters for cooling. The potential user must have access to the water, and the water ideally should have a low suspended load to reduce maintenance on the cooling system. A major problem is that use of the brackish waters can be accompanied by large growth of mollusks and other clogging organisms which can result in costly maintenance and repairs.

WATER POWER GENERATION

Many schemes have been promulgated to harness the energy of the tides for the generation of electric power. In the Passamaquoddy arm of the Bay of Fundy and in some parts of Cook Inlet, Alaska, the tide range is in excess of 25 feet. If the vast amount of energy involved in the water movement could be harnessed, a tremendous power source would become available. Unfortunately, tidal electric plants cannot compete economically with the fossil-fueled or nuclear thermo-electric plants. Even more important, power generation peaks would vary with tide fluctuations, not consumer demands. It appears there is very little potential for economic development of tidal power.

WASTE DISPOSAL

The concentration of population and industrial development in the estuarine zone has led naturally to the use of estuarine waters for removal of the waste materials of man's civilization from his immedi-

ate vicinity. It is unlikely that cities were built on the coastline with any conscious consideration of the use of the estuarine environment for waste disposal, yet it has happened that this use has become one of the major uses of estuarine waters and the associated land. Virtually all of the cities and industries in the coastal counties dispose of wastes either directly or indirectly into the estuarine zone.

Liquid waste discharges to estuarine systems include domestic waste products, industrial waste materials of all degrees of chemical complexity and sophistication, used cooling water with its thermal load, and storm runoff. These wastes affect the estuarine environment in different ways and can eliminate other beneficial uses (Figure IV.2.20).

Liquid wastes are not the only concern. The use of the estuarine shoreline for refuse dumps and land fills results in considerable debris getting into the water (Figure IV.2.21). Water leaching through these dumps has a pollutional impact on the estuarine water. Spoil disposal from dredging activities is another form of solid waste material that contributes to estuarine degradation (Figure IV.2 22). Solid materials entering the estuary in the form of debris from storm runoff can be significant in terms of damaging beneficial uses.

The impact of waste disposal on the estuarine environment will be discussed in Part IV, Chapter 5. In the context of estuarine uses

it is important to recognize, however, that waste disposal is a highly significant and universal use of the estuarine resource and that it is likely to remain so. Along with the many other socio-economic uses of the estuarine environment, it must be managed so that it does not damage the biophysical environment.

EXPLOITATION OF MINERAL RESOURCES

Minerals within the water, on the bottom, and under the bottom are a valuable part of the estuarine resource and are being exploited widely. Table IV.2.8 shows the extent of such exploitation in the estuarine zone.

Sub-bottom mining operations are limited to the recovery of sulphur, petroleum, and natural gas, with the major operations occurring in Louisiana, Texas, California, and Alaska (Figure IV.2.23). These operations exist both in the estuaries and out on the continental shelves with the governing criterion for location being the location of reserves; the carrying out of such operations does not require an extensive amount of local installation or development after drilling is finished.

Avery Island, Louisiana, for example, has over 100 oil wells in active production as well as some new drilling. Yet, the company exploiting the oil reserves has restored all abandoned well sites and taken special efforts to make their facilities blend into the natural environment

TABLE IV.2.8 MAJOR EXPLOITATION OF COASTAL MINERAL RESOURCES 1967

Biophysical Region[3]	Commodity[1]	No. of Operations	Quantity Produced[2] Amount	Units	Value[2] $
North Atlantic	Metals	45	1,668,058	Tons	7,251,772
	Sand and Gravel	116	10,068,000	Tons	10,611,000
	Clay	7	34	Tons	99
Middle Atlantic	Metals	73	8,805,909	Tons	15,878,611
	Sand and Gravel	232	12,299,000	Tons	20,193,000
	Clay	24	419,549	Tons	1,149,331
Chesapeake Bay	Metals	26	4,415,357	Tons	11,351,502
	Lime	3	6,034	Tons	114,580
	Sand and Gravel	140	3,451,000	Tons	3,511,000
	Clay	16	103,500	Tons	207,000
South Atlantic	Sand and Gravel	6	137,000		89,000
Gulf of Mexico	Petroleum	311	775,970	Barrels	92,138,579
	Natural Gas	830	12,977,008	Cu.Ft.	22,540,516
	Natural Gas Liquids	138	3,321,951	MG	64,513,281
	Metals	14	37,946	Tons	21,081
	Lime	2	3,057,318	Tons	23,413,877
	Sand and Gravel	29	3,848,950	Tons	6,991,125
	Clay	5	6,724,608	Tons	36,036,697
	Salt	1	2,743,450	Tons	21,337,860
	Sulphur	4	16,569	Tons	528,590
	Other Non-Metals	42	16,261,084	Tons	32,316,421
	Non-Metals	14	4,315,639	Tons	12,516,395
Pacific Southwest	Undistributed	23	1,009,793	Tons	55,997,873
	Other Mineral Fuels	334	3,127,128	MG	40,160,352
	Petroleum	465	214,807	Barrels	582,000
	Sand and Gravel	216	64,696,906	Tons	73,307,506
	Other Non-Metals	182	11,474,022	Tons	48,205,436
Pacific Northwest	Other Mineral Fuels	1	107,736	MG	898,430
	Sand and Gravel	155	26,750,606	Tons	34,447,779
	Other Non-Metals	127	7,856,956	Tons	13,721,602

1. Commodity classifications from U. S. Bureau of Mines, "Minerals Yearbook"

2. Quantities and values of some commodities are withheld to avoid disclosure of individual operations.

3. Data are not available for the Caribbean, Alaska, and Pacific Islands regions.

DATA SOURCE: U. S. Bureau of Mines

(Figure IV.2.24). This example is an exception to general practice, but nevertheless points out the resource exploitation is not necessarily synonomous with environmental destruction.

Recovery of minerals from submerged estuarine zone bottoms by surface mining, i.e., dredging, is primarily directed toward sand, gravel, and oyster shell production. Sand and gravel operations are prevalent throughout coastal areas wherever suitable deposits and a market exist. Most sand and gravel dredging operations supply nearby users; therefore, they tend to be distributed in relationship to construction and to population.

The concentration of population and industrial development in the estuarine zone, the accessibility of estuarine areas for sand and gravel dredging, and the efficiency of barge transport to coastal construction areas all tend to increase the pressure on submerged estuarine sand and gravel deposits, particularly as coastal shore deposits are exhausted. While no data are available on the present relative importance of shore and submerged deposits in the various biophysical regions, it is certain that all available sources of sand and gravel deposits will be exploited intensively.

Oyster shell production is an extremely useful construction material in the Gulf of Mexico biophysical region. Twenty of the twenty-two million tons of annual U.S. production are in the Gulf States with Texas and Louisiana producing the vast majority of it. The major

oyster shell deposits are in shallow embayments such as Galveston Bay, Texas, and Mobile Bay, Alabama.

Phosphate rock is an important estuarine mineral resource; about 75 percent of the total U.S. production is in the estuarine zone of Florida and North Carolina, particularly around Tampa Bay and Pamlico Sound. Considerable deposits of phosphate rock underlie much of the South Atlantic biophysical region, and these may be subject to future exploitation.

Ocean water is a great reservoir of dissolved minerals, some of which are extracted commercially. Installations in the estuarine zone in California, New Jersey, Texas, and Florida extract magnesium compounds from coastal ocean water and supply the bulk of U.S. production. Large ponds are used in California for the evaporation of saline water to produce commercial salt; many of these have been built in marshes or shallow estuarine waters.

SHORELINE DEVELOPMENT

The use or development of estuarine water either depends upon, or governs, land or shoreline use. Examination of some of the purposes of shoreline development illustrates this relationship.

Recreational shoreline development is based on potential water use. Recreational facilities included: Marinas which support boating activities; beaches which are necessary for the swimmers; parks that cater

to those seeking aesthetic enjoyment of the water; fishing piers and vacation cottages, motels, and hotels (Figure IV.2.13). Although the motels and hotels are a commercial venture, their prime purpose is to support the recreationalist. Finally, recreation sites provide the access needed to enjoy the water.

Residential developments breed water use because of the proximity of the water. In many communities the development of waterfront property subjects the shoreline to intensive housing development. This, in turn, is accompanied by a build-up of boat docks, fishing and swimming piers, and private beaches which are representative of the owner's affluence (Figure IV.2.14). Whether or not the water use is the primary motivation for the owner is not significant.

Commercial development of the shoreline includes docks and shipyards, loading terminals, the smaller municipal and local piers, industrial plants, and airports. These are all built to furnish a service and a profit return for the investors (Figure IV.2.16).

Transportation, both commercial and personal, is common to all other activities. In addition it requires highways, commercial port facilities, and airports (Figure IV.2.18). The land-water relationship of airports has been discussed previously. Highways are not directly related to water use but are an integrated part of land-water schemes. Highways along the shoreline usually involve the development of bridges and fills which provide a ready access to the water for aesthetic

appreciation and for fisherman. In addition, their protective facilities preserve the shoreline and make it available for use. This aspect is important because if the shoreline is not protected adequately, development uses must be foregone and the water becomes inaccessible.

Other structures built to protect the shoreline include bulkheads to hold the shore in place; dikes to prevent flooding and extend reclaimed land, jetties to provide a protective barrier between the sea and ship channels; and groins along beach areas to control sand movement (Figure IV.2.25).

SECTION 5. DELIBERATE MODIFICATION OF THE ESTUARINE ZONE

Deliberate modification programs are developed to intensify and support major uses. In the past many of these programs resulted in use damages far beyond the intended benefits, but the trends in present practice include attempts to predict unsought consequences. The overall impact of any modification scheme depends on the type and extent of the project.

The most common forms of modification are channel dredging for maintenance of navigation; construction of barriers to reduce damage from storm waves and tsunamis; the construction of dikes, jetties, and groins for navigation, storm protection, erosion control, and land reclamation purposes; wetland filling through dredging spoil disposal, land fill operations, and solid waste disposal; regulation of fresh water inflow for upstream water use or flood protection; and the construction of highway fills, causeways, bridges for land transportation. These modification activities may occur singly or in combination, but in general the result is the same. The estuarine zone form, structure, shape, salinity, and water movement patterns are affected to some degree.

The greatest percentage of deliberate modification of the estuarine zone is for the protection and maintenance of navigation. Almost every harbor area in the United States requires some form of dredging

maintenance to maintain access and berthing space. This may take the form of a channel six feet deep or one forty deep, depending upon the ship traffic. Table IV.2.9 shows the amount of dredging required by the Corps of Engineers to maintain the harbors of United States Ports.

Jetties are a less common item on the coastal scene. These structures are generally placed where it is necessary to protect a channel and are usually built only where narrow harbor entrances are subjected to shoaling and wave action. On the west coast of the United States jetties are often used to form harbor enclosures as in Los Angeles Harbor and Halfmoon Bay (Figure IV.2.25).

Groins are not too frequently used in the estuarine environment. Normally they are built along sandy coastal beaches to help control beach erosion. The groins effectively interfere with the littoral transport phenomena by trapping materials that would be carried away; they are used extensively along the east coast and in southern California.

Utilizing barriers to protect the land from the fury of storms at sea is a procedure that has been frequently proposed but little used. There are two examples of hurricane barriers along the east coast, in New Bedford, Mass., and Providence, R.I. Schemes have been developed for other hurricane barriers in Narragansett Bay and Tampa Bay but have not materialized. Feasibility investigations of a tsunami

TABLE IV.2.9
Annual Harbor and Channel Dredging and Maintenance Costs

Biophysical Region	Volume Dredged (Cu. Yds.)	Cost $	No. of Years of Record
North Atlantic	751,000	1,959,000	17
Middle Atlantic	5,241,000	5,542,000	18
Chesapeake Bay	6,123,000	3,140,000	18
South Atlantic	5,668,000	1,488,000	18
Caribbean	123,000	41,000	18
Gulf of Mexico	30,880,000	4,840,000	18
Pacific Southwest	166,200	156,000	18
Pacific Northwest	992,000	507,500	17
Alaska	6,900	5,400	19
Pacific Islands	74,200	157,400	18

REFERENCE: THE NATIONAL ESTUARINE INVENTORY

DATA SOURCE: U. S. ARMY CORPS OF ENGINEERS

barrier for Hilo Bay in Hawaii were conducted by the Corps of Engineers but no construction has taken place.

Major modifications of estuarine areas by land fill or marsh and wetland reclamation have occurred throughout the Nation. The area reclaimed is generally the highly productive tidal marsh which is so important to estuarine ecology. As an example, 80 percent of the

300 square miles of wetlands that originally surrounded San Francisco Bay have been filled. San Francisco Bay is not unique. Table IV.2. 10 lists areas of basic marsh and wetland habitat filled in the past 20 years. (Figure IV.2.26.) Expanding residential and commercial needs for more shoreline land and navigation spoil disposal requirements are the major causes of dredging and filling operations.

Two-thirds of the total marsh and wetland areas are important fish and wildlife habitat. Since the late 1940's, seven percent of the important habitat has been lost; the largest single block of this has been in the San Francisco Bay system, where much of the tidal marsh and shallow waters no longer exist.

The patterns of filling estuarine marsh and shallow water areas closely parallel population and industrial development within the estuarine zone. In North Atlantic and Middle Atlantic regions commercial development has been the major cause of the filling of estuarine areas; in Florida (which has parts in three biophysical regions) residential development has been the major reason for filling; in both Louisiana and Texas dredging and filling associated with oil and gas exploration has been the major cause for estuarine physical modification.

Estuarine modifications due to control and regulation of tributary freshwater streams may be unsought consequences rather than deliberate developmental schemes. Many of the Nation's major river

TABLE IV.2.10 ESTUARINE HABITAT REMOVED BY DREDGING AND FILLING OPERATIONS

BIOPHYSICAL REGION	AVAILABLE HABITAT IN 1955 (ACRES)		HABITAT LOST, 1947-1967	
	AREA OF TOTAL MARSH AND WETLAND	AREA OF IMPORTANT WILDLIFE HABITAT	AREA DREDGED AND/OR FILLED	PERCENT OF HABITAT LOST
NORTH ATLANTIC	168,000	167,000	4,000	7.0
MIDDLE ATLANTIC	424,000	424,000	89,000	8.6
CHESAPEAKE BAY	441,000	428,000	3,000	0.5
SOUTH ATLANTIC	1,551,000	797,000	25,000	2.3
CARIBBEAN (FLORIDA ONLY)	469,000	99,000	15,000	7.5
GULF OF MEXICO	6,000,000	3,426,000	167,000	4.8
PACIFIC SOUTHWEST	165,000	162,000	256,000	67.0
PACIFIC NORTHWEST	174,000	98,000	5,000	4.0
ALASKA	INSUFFICIENT	DATA	1,100	0.2
PACIFIC ISLANDS	10			
TOTAL	9,392,000	6,175,000	565,100	7.0

REFERENCES: U.S.D.I., FISH & WILDLIFE CIRCULAR 39, 'WETLANDS OF THE UNITED STATES.' 1956
U.S.D.I., FISH & WILDLIFE SERVICE DATA PRESENTED IN CONGRESSIONAL HEARINGS, 'ESTUARINE AREAS', HOUSE SERIAL # 90-3.

basins have been subjected to some type of major waste resource development, as shown in Table IV.2.11. These include flood control, public water supply, power generation, or navigation projects. Generally, the more densely populated and the more arid States have accomplished, out of necessity, greater control of the surface water resources.

California is investing over $2 billion to conserve the surplus water in the northern half of the State and transport it to the southern half. This great effort requires interbasin diversions from coastal basins and results in much different fresh water inflow patterns in the estuarine areas. Texas is also developing its water resources according to a carefully developed plan. Florida has built numerous flood control works which have affected the drainage from Lake Okeechobee into the Everglades and have altered the estuarine environment. The Savannah River in Georgia is fairly well-regulated by two upstream reservoirs. The Roanoke River in Virginia and North Carolina is regulated, as is the Susquehanna in Maryland and Pennsylvania. There are numerous control structures on small coastal streams in New Hampshire and Oregon.

The Columbia River in Washington and Oregon is one of the most fully developed large rivers in the country. This flow regulation has had an impact on estuarine ecology, especially the anadromous fish runs.

TABLE IV 2 11 MAJOR FLOW REGULATION STRUCTURES ON ESTUARINE TERMINATING STREAMS

BIOTIC REGION	STATE	RIVER NAME	PURPOSE	ACTIVE STORAGE VOLUME
NORTH ATLANTIC	MAINE	ST.CROIX	LOG DRIVING,POWER	187,100
		GRAND LAKE STREAM	POWER	161,000
		SEBEC		57,400
		W.BR. PENOBSCOT	LOG DRIVING,POWER	344,000
		E.BR. PENOBSCOT	LOG DRIVING,POWER	41,000
		WEBSTER BROOK	LOG DRIVING,POWER	116,000
		KENNEBEC	POWER	60,000
		KENNEBEC	LOG DRIVING,POWER	544,900
		OSSIPEE	POWER,RECREATION	23,000
	MASSACHUSETTS	NASHUA	MUNICIPAL,POWER	171,800
		COMAS	MUNICIPAL,POWER	16,600
		MERRIMAC	FLOOD CONTROL	153,700
		WINNEPESAKEE	POWER,RECREATION	38,000
MIDDLE ATLANTIC	CONNECTICUT	NATCHANG	FLOOD CONTROL, RECREATION	52,000
		E.BR. FARMINGTON	MUNICIPAL	68,710
		W.BR. FARMINGTON	MUNICIPAL	20,000
		SWIFT-WESTFIELD	MUNICIPAL,POWER	1,234,000
		LITTLE	MUNICIPAL,POWER	70,000
		NAUGATUCK	FLOOD CONTROL, RECREATION	42,000
		SAUGATUCK	MUNICIPAL	15,600
	NEW JERSEY	ESOPUS	MUNICIPAL,RECREATION	392,378
	N.JERSEY,DELAWARE,PENNSYLVANIA	E.BR. DELAWARE	MUNICIPAL,POWER, RECREATION	453,480
CHESAPEAKE BAY	MARYLAND	SUSQUEHANNA	MUNICIPAL,POWER	70,000
		PATUXENT	MUNICIPAL,RECREATION	18,100
		N.BR. PATAPSCO	MUNICIPAL	129,115
		GUNPOWDER	MUNICIPAL	72,520
SOUTH ATLANTIC	NORTH CAROLINA	ROANOKE	FLOOD CONTROL,INDUSTRY,POWER,RECREATION,LOW FLOW AUGMENTATION	2,110,500
	SOUTH CAROLINA	SANTEE	NAVIGATION,POWER	1,099,900
		COOPER	NAVIGATION,POWER	761,500
	SOUTH CAROLINA, GEORGIA	SAVANNAH	FLOOD CONTROL,NAVIGATION,POWER	1,730,000
GULF	FLORIDA	APALACHICOLA	NAVIGATION,POWER, RECREATION	425,900
	ALABAMA	TALLAPOOSA	POWER	1,375,000
		TOMBIGBEE	NAVIGATION	117,000
	TEXAS	NUECES	IRRIGATION,MUNICIPAL,RECREATION, INDUSTRIAL	185,800
		MEDINA	IRRIGATION	254,000
		COLORADO	FLOOD CONTROL,IRRIGATION,MUNICIPAL, POWER,RECREATION, INDUSTRIAL	1,922,000
		RIO GRANDE	IRRIGATION	
	LOUISANA	BUFFALO BAYOU	FLOOD CONTROL	127,900
PACIFIC SOUTHWEST	CALIFORNIA	CALAVERAS	MUNICIPAL	968,000
		SACRAMENTO	FLOOD CONTROL,POWER,IRRIGATION	4,377,000
		CACHE	IRRIGATION,RECREATION	319,000
		SAN JACINTO	IRRIGATION	12,000
		SANTA ANA	FLOOD CONTROL	217,000
		TUJUNGE	FLOOD CONTROL	32,000
		SAN GABRIEL	FLOOD CONTROL	33,400
		LOS ANGELES	FLOOD CONTROL	17,300
		COTTONWOOD	MUNICIPAL	44,040
		SWEETWATER CREEK	IRRIGATION,MUNICIPAL	27,690
PACIFIC NORTHWEST	OREGON	COLUMBIA-DAMS,LOCKS	NAVIGATION,POWER	87,000
		WILLAMETTE-LOCKS	NAVIGATION	
	WASHINGTON	WHITE	FLOOD CONTROL	106,000
		BAKER	POWER	142,370
	WASH.,CANADA	WHATCOM	MUNICIPAL	26,400
ALASKA	ALASKA	SOUR MILL CREEK	DESILTING,INDUSTRIAL	150,000
		PURPLE LAKE	POWER	25,000
		ANNEX CREEK	POWER	23,360
		COOPER CREEK	POWER	108,000
		EKLUTNA	POWER,RECREATION	163,300
PACIFIC ISLANDS	HAWAII	FRESH WATER HOLDING DITCHES	WATER SUPPLY RETENTION	

• NO INFORMATION AVAILABLE ON VOLUME

REFERENCE THE NATIONAL ESTUARINE INVENTORY
DATA SOURCES U S GEOLOGICAL SURVEY, U S ARMY CORPS OF ENGINEERS

There has been considerable modification in the estuarine systems from freshwater flow regulation. Modification of the estuary was not the primary objective of the regulatory projects but occurred as an unsought consequence. Future water resource development schemes will have to consider the estuarine impact to insure that detrimental effects are kept at a minimum.

SECTION 6. SUMMARY

The single great unique feature of the estuarine zone, which makes it of primary importance to man and his civilization, is its role in the life cycle of many animals which aid in converting solar energy into more usable forms. While no life form can be singled out as irreplaceable, the kinds of life which need the estuarine zone to survive represent essential links in the energy conversion chain upon which man depends for survival.

Many of the uses catalogued in this chapter occur only because the historical growth of the country makes the estuarine zone the place where people and industry are. Only commercial navigation, naval use, and commercial fishing are uses which are primarily associated with the estuarine zone, rather than other parts of man's environment. Uses such as water supply, waste disposal, and recreation are associated with civilization wherever it exists; in the estuarine zone they may have different values, different emphasis, or different impact on the biophysical environment.

This chapter points out the intrinsic importance of the estuarine zone as a feature of the human environment. The mere cataloguing of uses gives no measure of the total value of the estuarine environment to man and his civilization, because each identifiable use is merely a single example of how man has found a way to exploit an estuarine

resource for his benefit.

Very rarely does an individual or an organization use an estuarine area for only one purpose. Tourists may come for recreation, but they also dispose of their wastes in the estuarine zone. An industry may use an estuary for shipping and for waste disposal, but many of its employees will be sport fishermen or boating enthusiasts who use the estuary for recreation. The fishermen and oystermen who harvest the living resources still need navigation channels and docks for their boats.

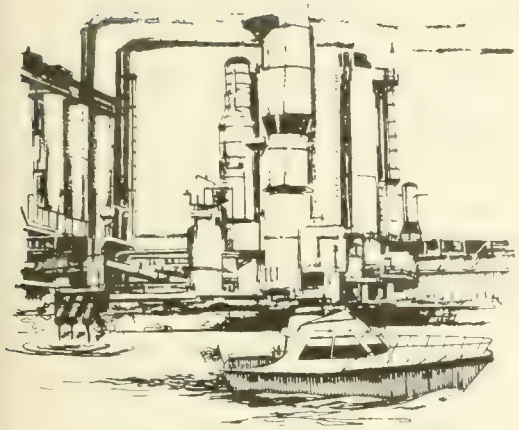
The value and the importance of the estuarine zone lie in the great number of ways in which it can serve human society. Multiple use of the estuarine resource is an intrinsic feature of the socioeconomic environment of the estuarine zone, and those estuarine systems which can be used intensively for many purposes are the most valuable components of the national estuarine system.

REFERENCES

IV-2-1 Battelle Memorial Institute, The Economic and Social Importance of Estuaries (a report prepared under contract No. 14-12-115 with FWPCA, as part of the National Estuarine Pollution Study). Columbus, Ohio, Battelle Memorial Institute, 1968.

Chapter 3

THE SOCIAL AND ECONOMIC VALUES OF ESTUARINE USE



Chapter 2 described the most important uses of the estuarine zone. There are a variety of uses associated with demographic and industrial development in the coastal counties; each biophysical region has very similar kinds of uses to the others, but there are differences in intensity of certain kinds of use in different biophysical regions, and also in individual areas within regions.

Such differences tend to be related to the availability for exploitation of a particular kind of resource; such as sunshine and beaches in Florida, oil in Texas and Louisiana, deep safe harbors at New York and San Francisco, salmon runs in Washington and Alaska. Each of these stimulates emphasis in estuarine exploitation for a particular kind of use, sometimes to the extent of excluding all other uses either by expropriating all available space or damaging the environment for other uses.

Estuarine use is a complex assortment of interlocking and overlapping types of estuarine resource exploitation.

All of such uses have value, both individually and as part of the development and use of the entire estuarine resource for the benefit of the present and future national community. The mission of this chapter is to show that the importance and total value of any estuarine system lie not in the measure of economic value for any particular use, but in multiplicity of use related to the needs of people who live there or otherwise depend on the estuarine resource.

The approach used is two fold. First, the overall economic development of the estuarine zone and the economic values of several individual uses show the relationship of one use to other uses. Then the balance of uses in several estuarine systems shows the relationship of community needs to estuarine uses.

The common denominator in this discussion is people; their economic needs combined with their social desires and values are what determines the socioeconomic demands on the biophysical estuarine environment.

SECTION 1. ECONOMIC DEVELOPMENT OF THE ESTUARINE ZONE

Estuarine areas have been a key factor in the development of our Nation. Long before the settlement of Plymouth, British, French, and Spanish fishermen were exploring the North Atlantic fishery resources including those in the Gulf of Maine and along Georges Bank. The need for shore bases to support the cod fishery of the New England coast was a significant factor in stimulating exploration and settlement.

After colonization of New England, the fisheries were the sustaining industry that provided the economic foundation for growth and development. The role of the estuarine zone in supporting the fishery operations was extensive: By necessity most of the inhabitants settled near the natural harbors; fish was the main food staple and the main export; the harbors were the focal point for incoming ships and served as the only commercial centers. The resources of the sea and waterborne commerce were the economic mainstay of the developing Nation; much of the development of California was dependent on ships sailing around the tip of Cape Horn, South America, and this development of trade centered on the west coast opened up new vistas for commercial activity.

The estuaries were also the entry portal for the immigrants that came to this Nation looking for the land of opportunity. It is little

wonder that most of the major cities of the United States are positioned on a natural estuarine harbor.

As the population grew, the relative importance of the fishery progressively declined as economic growth in other industries outstripped the demand for seafood as a staple diet item. The growth of industrial and population centers in the estuarine zone closely paralleled the growth of the rest of the Nation, with the estuarine zone becoming relatively more important in international commerce and less important in agricultural food production than the interior of the country.

URBAN AND AGRICULTURAL DEVELOPMENT

Table IV.3.1 shows present population and agricultural development in the estuarine zone.* This table illustrates very clearly the existence of several distinct environments in the estuarine zone. Population and agricultural data exist in political subdivision groupings, while the Standard Metropolitan Statistical Areas (SMSA) cross State and county boundaries to present unified economic groupings. It happens that the classification by biophysical regions cuts across the boundaries of some political subdivisions, but is compatible with the SMSA economic units.

The differences in boundaries of these environments is one of the key problems with which estuarine zone management must deal; in the

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*In this, as in many other tables requiring nationwide socioeconomic statistics, 1960 is the last year for which consistent data are available to support regional comparisons.

TABLE IV.3.1 POPULATION AND AGRICULTURE IN THE ESTUARINE ZONE, 1960

BIOPHYSICAL REGIONS AND STATES	STATE POPULATION DENSITY (PERSONS PER SQ MILE)	% COASTAL COUNTIES POPULATION	COASTAL URBAN POPULATION	COASTAL COUNTIES POPULATION DENSITY (PERSONS PER SQ MILE)	COASTAL COUNTY LAND IN FARMS (PERCENT)	COASTAL COUNTY TIDAL SHORELINE DENSITY: POPULATION DENSITY (PERSONS PER SQ MILE)	COASTAL COUNTY TIDAL SHORELINE DENSITY: FARMLAND (SQ MI/MI)	TOTAL COASTAL COUNTIES POPULATION IN SMSAS (PERCENT)	TOTAL COASTAL COUNTIES POPULATION (PERCENT)
NORTH ATLANTIC		[illegible]	[illegible]	[illegible]	17.6	740	.45	100	5.6
MAINE	41			41	21.6				
NEW HAMPSHIRE	87			140	22.7				
**MASSACHUSETTS	697			497	17.7				
						2,800	.68	93	38.1
MIDDLE ATLANTIC		22,447,123	21,852,[illegible]	1,165	28.1				
**MASSACHUSETTS	697			713	16.2				
RHODE ISLAND	810			815	17.9				
CONNECTICUT	521			533	17.6				
NEW YORK	381			5[illegible]	4.5				
NEW JERSEY	816			823	17.1				
PENNSYLVANIA	191			[illegible] 191	26.4				
DELAWARE	225			225	54.8				
**MARYLAND	314			5	45.2				
**VIRGINIA	109			433					
**NORTH CAROLINA	33			40	38.6				
CHESAPEAKE BAY		5,137,424	4,954,30[illegible]	370	38.0	340	.96	97	8.8
**MARYLAND	314			337	51.5				
**VIRGINIA	109			258	32.6				
D.C. OF COLUMBIA	13,442			12,442	0.0				
SOUTH ATLANTIC		[illegible]	1,659,[illegible]	89	21.6	225	.80	75	3.8
**NORTH CAROLINA	73			41	27.5				
SOUTH CAROLINA	73			68	30.[illegible]				
GEORGIA	58			42	15.9				
**FLORIDA	92			128	42.6				
CARIBBEAN		[illegible]	335,[illegible]			1,070		25	6.3
**FLORIDA	92			211	11.7				
PUERTO RICO	647			647					
VIRGIN ISLANDS	133			133	52.2				
GULF OF MEXICO		[illegible]	3,[illegible]	121	49.1	380	1.53	53	10.0
**FLORIDA	92			95	34.8				
ALABAMA	64			129					
MISSISSIPPI	49			105					
LOUISIANA	72			119					
TEXAS	36			146					
PACIFIC SOUTHWEST		[illegible]	[illegible]	391	48.1	3,980	4.90	99	20.7
**CALIFORNIA	100			391	48.1				
PACIFIC NORTHWEST		[illegible]	[illegible]	49	15.1	650	1.35	77	5.3
**CALIFORNIA	100			27	20.0				
OREGON	17			58	18.5				
WASHINGTON	43			97	15.5				
ALASKA	0.4	168,721	85,531	1.51	<1.0	5	0.07	50	0.3
PACIFIC ISLANDS		632,772	5[illegible],000		64.7	480	3.37	79	1.1
HAWAII	89			89	64.7				
GUAM	316			316	24.0				
AMERICAN SAMOA	254			264					

* BASED ON STANDARD METROPOLITAN STATISTICAL AREAS (SMSA), EXCEPT FOR ALASKA, WHICH ARE THOSE COMMUNITIES WITH A POPULATION DENSITY OF OVER 1.00 PERSONS PER SQUARE MILE.

**STATES WITH AREA IN MORE THAN ONE BIOPHYSICAL REGION.

REFERENCE: THE NATIONAL ESTUARINE INVENTORY
SOURCE: U.S. DEPT. OF COMMERCE, BUREAU OF THE CENSUS,
U.S. COAST AND GEODETIC SURVEY

present discussion the primary concern is with the biophysical environment of the estuarine zone, and the regions describing this environment are the basic unit for analysis. Where necessary political subdivisions have been broken at county boundaries as required to present a consistent analysis.

The coastal counties contain only 15 percent of the land area of the United States, but within this area is concentrated 33 percent of the Nation's population, with about four-fifths of it living in primarily urban areas which form about ten percent of the total estuarine zone area. Another 13 percent of the estuarine land area is farmland, but this accounts for only four percent of the total agricultural land of the Nation. The estuarine zone, then, is nearly twice as densely populated as the rest of the country, and supports only one-fourth as much agriculture per unit area.

The magnitude of population and agricultural development in the estuarine zone is shown in Table IV.3.1 by densities in terms of tidal shoreline. The few estuarine areas in the Pacific Southwest show the greatest shoreline development for both living and farming as shown by the population density of 3,980 persons per mile of tidal shoreline and a farmland density of 4.9 acres per mile. The Middle Atlantic region, in contrast, has a very high population density and a low farmland density, showing how in this region the estuarine zone developed as a center of population while agriculture developed elsewhere.

The difference in estuarine land use development between these two regions probably results from the difference in rainfall. The low rainfall in the Pacific Southwest required the intensive use for farming of all land amenable to irrigation, of which a major part was that near the mouths of the major rivers. The plentiful rainfall in the Middle Atlantic region, however, permitted the use of much land away from the estuarine zone for farming, so the intensive estuarine land use pattern of the Pacific Southwest did not develop.

In those regions lying between Cape Hatteras and Canada, as well as in the Pacific Southwest, over 90 percent of the population lives in urban areas; over much of the Atlantic estuarine zone stretches the great Northeastern megalopolis with population densities averaging over 1,000 persons per square mile. The remainder of the estuarine zone of the United States exhibits a pattern of major centers of population clustered around natural harbors and separated by stretches of coastline which are either empty and inaccessible or beginning to be sprinkled with private residences and resort communities in the vicinities of population centers.

Agriculture in the estuarine zone itself tends to follow the crop patterns typical of neighboring inland areas, although there are some important crops which require special conditions of humidity or soil dampness most easily found in the estuarine zone, if not directly associated with estuarine waters themselves. Cranberries

in New Jersey and Massachusetts, rice in Texas and Louisiana, and sugarcane in Hawaii, Louisiana, Florida, and Puerto Rico are examples.

INDUSTRIAL DEVELOPMENT

Table IV.3.2 gives a general picture of the extent of industrial development in the estuarine zone. The coastal counties have within their borders 40 percent of all manufacturing plants in the United States, thus closely paralleling population concentration into the estuarine zone. The mixture of manufacturing types in the estuarine zone is the same as the national composition with only minor exceptions, such as the concentration of the apparel manufacturing industry in the Middle Atlantic region, particularly in the New York area. Distribution of manufacturing types among the biophysical regions shows regional differences related to historical development as well as raw material and market availability.

Over half of all plants in the coastal counties and one-fifth of all manufacturing plants in the United States are located in the Middle Atlantic biophysical region, which was the historical center of the Nation's industrial growth and is still one of the major market areas. The Pacific Southwest is the major industrial center of the Pacific coast, and its tidal shoreline now has the same intensity of development as that of the Middle Atlantic region. Some industrial development in other regions tends to follow historical

TABLE IV-32 EXTENT OF INDUSTRIAL DEVELOPMENT IN THE ESTUARINE ZONE

BIO-PHYSICAL REGIONS	TOTAL # OF PLANTS	NUMBER OF PLANTS WITH >20 EMPLOYEES				MAJOR INDUSTRIES IN REGION (PLANTS WITH >20 EMPLOYEES				DENSITY OF IND. DEVEL. (# OF PLANTS / MILE OF TIDAL SHORE LINE
		TOTAL	MAJOR WATER USE INDUSTRIES			INDUSTRY GROUP	# OF PLANTS	% OF TOTAL PLANTS IN REGION	% OF INDUSTRY GROUP IN ESTUARINE ZONE	
			PAPER & ALLIED PRODS.	CHEMICAL & ALLIED PRODS.	PETROLEUM & ALLIED PRODS.	PRIMARY METALS IND.				
NORTH ATLANTIC	8617	2933	132	88	13	60	APPAREL,OTHER TEXTILE PRODUCTS	368	12.5	9.4	0.7
							LEATHER & LEATHER PRODUCTS	342	11.7	34.0	
							FABRICATED METAL PRODUCTS	225	7.8	6.7	
							MACHINERY & ELECTRICAL EQUIPMENT	493	16.5	13.0	
							FOOD & KINDRED PRODUCTS	325	11.1	7.8	
MIDDLE ATLANTIC	65300	21947	761	940	78	532	APPAREL,OTHER TEXTILE PRODUCTS	6547	30.0	29.9	2.7
							PRINTING & PUBLISHING	1701	7.8	56.5	
							FABRICATED METAL PRODUCTS	1677	7.7	49.6	
							MACHINERY & ELECTRICAL EQUIPMENT	2353	10.8	48.1	
							TEXTILE MILL PRODUCTS	1293	5.9	29.4	
							FOOD & KINDRED PRODUCTS	1413	6.5	33.2	
CHESAPEAKE BAY	5186	2764	86	127	13	411	FOOD & KINDRED PRODUCTS	513	24.7	12.1	0.4
							PRINTING & PUBLISHING	243	11.6	8.0	
							FABRICATED METAL PRODUCTS	158	7.7	6.7	
							APPAREL & OTHER TEXTILE PRODUCTS	191	9.3	2.3	
							LUMBER & WOOD PRODUCTS	142	6.9	8.7	
							STONE,CLAY,& GLASS PRODUCTS	133	6.4	9.8	
SOUTH ATLANTIC	2295	623	40	59	12	176	FOOD & KINDRED PRODUCTS	144	23.7	3.9	0.07
							LUMBER & WOOD PRODUCTS	92	14.0	6.0	
							STONE,GLASS,& CLAY PRODUCTS	57	9.7	4.9	
							* CHEMICALS AND ALLIED PRODUCTS	53	8.5	3.4	
							PRINTING & PUBLISHING	51	7.4	1.7	
CARIB-BEAN	2554	654	18	16	5	9	APPAREL & OTHER TEXTILE PRODUCTS	123	18.8	1.5	0.2
							FABRICATED METAL PRODUCTS	75	11.5	2.2	
							FURNITURE & FIXTURES	55	8.6	4.8	
							PRINTING & PUBLISHING	54	8.3	1.8	
							FOOD & KINDRED PRODUCTS	81	12.4	1.9	
GULF OF MEXICO	6939	2013	70	192	62	81	FOOD & KINDRED PRODUCTS	423	24.5	11.7	0.1
							FABRICATED METAL PRODUCTS	215	10.7	5.4	
							* CHEMICALS AND ALLIED PRODUCTS	192	9.5	11.2	
							MACHINERY,EXCEPT ELECTRICAL	161	8.0	5.5	
							STONE,CLAY,& GLASS PRODUCTS	168	8.3	12.3	
							LUMBER & WOOD PRODUCTS	123	6.1	7.6	
PACIFIC SOUTH-WEST	2750	763	249	132	24	248	FOOD & KINDRED PRODUCTS	245	11.1	20.1	2.5
							APPAREL & OTHER TEXTILE PRODUCTS	245	11.1	10.3	
							PRINTING & PUBLISHING	155	7.1	13.1	
							ELECTRICAL EQUIPMENT	194	8.7	24.9	
							FABRICATED METAL PRODUCTS	187	11.9	25.6	
							TRANSPORTATION EQUIPMENT	123	5.6	37.1	
PACIFIC NORTH-WEST	2594	1394	76	55	14	47	FOOD & KINDRED PRODUCTS	223	16.2	40.8	0.4
							LUMBER & WOOD PRODUCTS	533	38.7	40.8	
							FABRICATED METAL PRODUCTS	115	6.4	3.4	
							MACHINERY,EXCEPT ELECTRICAL	97	5.4	3.9	
							PRINTING & PUBLISHING	93	5.2	3.1	
							* PAPER & ALLIED PRODUCTS	76	4.2	5.2	
ALASKA	303		DATA	NOT	AVAILABLE		FOOD & KINDRED PRODUCTS				
PACIFIC ISLANDS	672	144	26	4	NO DATA	NO DATA	FOOD & KINDRED PRODUCTS	751	37.8	1.8	0.1
							TEXTILE MILL PRODUCTS	371	19.1	2.3	
							* PAPER & ALLIED PRODUCTS	251	13.4	1.8	
							LUMBER & WOOD PRODUCTS	131	9.8	1.2	
TOTAL ESTUARINE ZONE	1267796	39835	1449	1717	251	1046	APPAREL & OTHER TEXTILE PRODUCTS	8232	20.7		
							FOOD & KINDRED PRODUCTS	4139	10.5		
							FABRICATED METAL PRODUCTS	3381	8.5		
							PRINTING & PUBLISHING	3011	7.6		
							MACHINERY,EXCEPT ELECTRICAL	2475	6.2		
							ELECTRICAL EQUIPMENT	2315	5.8		
							* CHEMICALS & ALLIED PRODUCTS	1717	4.3		
							LUMBER & ALLIED PRODUCTS	1623	4.1		
							TEXTILE MILL PRODUCTS	1613	4.0		
							* PAPER & ALLIED PRODUCTS	1449	3.6		
							STONE,CLAY,& GLASS PRODUCTS	1361	3.4		
							FURNITURE & FIXTURES	1175	2.9		
TOTAL UNITED STATES	3266191	293551	3552	3985	889	3585	FOOD & KINDRED PRODUCTS	14113	14.1		
							APPAREL & OTHER TEXTILE PRODUCTS	13011	13.0		
							FABRICATED METAL PRODUCTS	212	9.2		
							MACHINERY,EXCEPT ELECTRICAL	8426	8.4		
							PRINTING & PUBLISHING	7215	7.2		
							LUMBER & WOOD PRODUCTS	5765	5.8		
							ELECTRICAL EQUIPMENT	4722	4.7		
							STONE,CLAY,& GLASS PRODUCTS	4655	4.7		
							TEXTILE MILL PRODUCTS	4367	4.4		
							* CHEMICALS & ALLIED PRODUCTS	3995	4.0		
							* PRIMARY METAL INDUSTRIES	3585	3.6		
							* PAPER & ALLIED PRODUCTS	3552	3.6		

* MAJOR WATER USE INDUSTRIES

REFERENCE: U.S. CENSUS OF MANUFACTURERS,1964
NATIONAL ESTUARINE INVENTORY

or present raw material availability. Leather product plants are clustered in the North Atlantic region, and lumber manufacturing plants are most plentiful in the Pacific Northwest. Food processing plants, however, follow closely the distribution of population.

While much of the industrial development located in coastal counties affects the estuarine zone indirectly through use of adjacent land, some of the water-using industries have an impact on the estuarine zone far beyond their numbers. The paper, chemical, petroleum, and primary metals industries are the major water users among manufacturing establishments; these are listed separately in Table IV.3.2 to show how universally these industries are distributed throughout the estuarine zone. The brackish estuarine waters may become an increasingly important source of water supply for industries, and for municipalities as desalting technology improves.

LAND OWNERSHIP

Out of the millions of acres of land contiguous to the estuarine zone, only a relatively small amount is relegated to urban development and farmland. A considerable portion is in the form of unused or undeveloped land, the ownership of which has an important bearing on future use of the estuarine environment. Privately owned land is subject to possible industrial or real estate development which could add significantly to water quality problems. Publicly owned land, on the other hand, represents the potential for

development of a broad-based public use with proper controls. It also indicates the potential for public access to the water. Table IV.3.3 summarizes land ownership in the coastal counties within each biophysical estuarine region. Except for Alaska, the great preponderance of estuarine zone land is in private ownership. The North Atlantic, Middle Atlantic, and Chesapeake Bay regions in particular have little land in these counties still remaining under public ownership. Detailed information on actual or potential use of these privately owned lands is not available; it is certain, however, that some commercial or residential use exists or is intended in most cases.

TABLE IV.3.3 LAND USE DISTRIBUTION IN THE ESTUARINE ZONE

BIOPHYSICAL REGION	AREA (SQ. MI.) INCORPORATED IN: METROPOLITAN AREAS	FARMS	PARKS, REC. AREAS, REFUGES, FORESTS, ETC.	NATIONAL DEFENSE INSTALLATIONS *	REMAINDER OF AREA IN COASTAL COUNTIES
NORTH ATLANTIC	1,744	1,965	347	16	7,121
MIDDLE ATLANTIC	10,374	5,403	1,172	51	2,288
CHESAPEAKE BAY	5,401	5,272	662	52	2,524
SOUTH ATLANTIC	7,569	7,840	2,919	26	6,511
CARIBBEAN (FLORIDA ONLY)	2,042	778	2,370	3	3,931
GULF OF MEXICO	11,929	23,620	6,275	21	6,327
PACIFIC SOUTHWEST	16,192	15,210	7,324	59	**
PACIFIC NORTHWEST	14,117	6,440	18,734	18	3,477
ALASKA (TOTAL STATE)	100	3,060	20,626	5	323,787
PACIFIC ISLANDS	598	3,677	38170	14	3,240

* NUMBER OF INSTALLATIONS ONLY. AREAS CLASSIFIED.
** MUCH FARMLAND IS WITHIN SMSA BOUNDARIES, DISTORTING TOTALS.

REFERENCE: NATIONAL ESTUARINE INVENTORY

SOURCES: U.S. DEPARTMENTS OF HOUSING AND URBAN DEVELOPMENT, AGRICULTURE, COMMERCE, DEFENSE, AND INTERIOR

SECTION 2. THE VALUES OF INDIVIDUAL USES

FISH AND WILDLIFE HABITAT

The value of the estuarine zone as fish and wildlife habitat both depends on and augments its value for other uses, particularly recreation and commercial fishing.

There is, in addition to these, the basic incalculable value of the estuarine habitat as a link in the essential energy-conversion chain which permits man to survive at all.

The trapping of fur bearers in the marshes of the Gulf and Atlantic represents one of the few economic values directly attributable to estuarine habitat. Louisiana is the major producer; in the 1965-1966 season total sales were 4.6 million dollars out of the nation's 6 million-dollar total. These included the pelts and some meat from nutria, muskrat, raccoons, mink, and otter, with much of the harvest coming from marshes managed specifically for that purpose.

The management of marshes for fur bearers requires periodic burning over, means of controlling predators, and the control of saline water intrusion. This makes the marshes so managed unsuitable for some other forms of estuarine-dependent life such as

shrimp; so against the economic value of marsh management for commercial trapping must be set the unknown cost of the loss of habitat for other forms of life.

The harvesting of pelts in the estuarine zone is of small economic value even when the four-million-dollar per year fur seal harvest of the Pribiloff Islands is included. As a measure of the full value of estuarine habitat this annual value is an excellent indicator of how the measurable economic worth of an estuarine use may reflect very little of its actual importance.

COMMERCIAL FISHING

The economic value of the estuarine zone to even such an obviously estuarine-dependent industry as commercial fishing can be established only with numerous assumptions and approximations. Not only is the existence of much of the harvestable crop dependent on the estuarine habitat, but the estuarine zone also provides the safe harbors without which the ocean fisheries could not exist. In addition, the sea food processing plants which supply the entire Nation are nearly all located in the estuarine zone and derive economic benefit from the existence of the commercial fishing industry.

In 1967 United States fishermen received $438 million dollars for approximately 4.06 billion pounds of commercial fish and shellfish. It has been estimated that two-thirds of the total value, or approximately $300 million dollars, can be considered for estuarine-dependent species. This is a conservative estimate of the direct value derived from the estuarine fishery for it does not include the value of fish harvested by foreign vessels off the United States coast. Five of the six leading species by weight, representing over one-half of the United States commercial fish tonnage in 1967, are estuarine-dependent (Table IV.3.4).

Table IV.3.5 shows the weight and values of the major estuarine-dependent commercial fish landings by biophysical region. The Gulf of Mexico region fishery has by far the greatest volume and value, primarily due to landings of shrimp and menhaden, which use the estuarine zone as a nursery area. The anadromous salmon fisheries of Alaska and the Pacific Northwest rank second, and the fisheries of estuarine-resident oysters in the Chesapeake are third in the Nation among the estuarine-dependent species.

TABLE IV.3.4
Ranking of the Ten Most Important Commercial Fisheries in the United States

1965

By Weight Thousand Pounds			By Value Thousand Dollars		
Rank	Kind	Weight	Rank	Kind	Value
1	Menhaden	1,726,104	1	Shrimp	82,409
2	Crabs	334,599	2	Salmon	65,123
3	Salmon	326,806	3	Tuna	41,734
4	Tuna	318,895	4	Crabs	30,745
5	Shrimp	234,644	5	Oysters	27,867
6	Flounders	180,121	6	Menhaden	27,073
7	Haddock	133,892	7	Lobsters	25,584
8	Sea Herring	110,293	8	Flounders	17,948
9	Ocean Perch	83,608	9	Clams	16,000
10	Whiting	82,574	10	Haddock	13,630
		3,540,536			348,113

1967

By Weight Thousand Pounds			By Value Thousand Dollars		
Rank	Kind	Weight	Rank	Kind	Value
1	Menhaden	1,165,800	1	Shrimp	103,100
2	Tuna	329,000	2	Salmon	48,600
3	Crabs*	316,000	3	Tuna	44,514
4	Shrimp	312,200	4	Oysters	31,600
5	Salmon	206,400	5	Crabs	27,100
6	Flatfish	110,900	6	Lobsters	24,100
7	Haddock	98,500	7	Clams	19,000
8	Sea Herring	85,100	8	Menhaden	15,200
9	Ocean Perch	71,500	9	Flatfish	13,600
10	Anchovies	69,600	10	Haddock	10,500
		2,765,000			337,314

Sources: Charles H. Lyles, "Fisheries of the United States... 1965," Stat. Dig, 59 (April, 1966), p. 4
Charles H. Lyles,"Fisheries of the United States..., 1967," C.F.S. No. 4700 (April, 1968), p.4.

*The crab landings include the King Crab, which is not an estuarine-dependent specie.

TABLE IV.3.5 COMMERCIAL LANDINGS OF MAJOR ESTUARINE-DEPENDENT FISH AND SHELLFISH 1965 (IN THOUSANDS)

NAME	BIOPHYSICAL REGION										TOTAL UNITED STATES
	NORTH ATLANTIC	MIDDLE ATLANTIC	CHESA-PEAKE BAY	SOUTH ATLANTIC	* CARIBBEAN	GULF OF MEXICO	PACIFIC SOUTHWEST	PACIFIC NORTHWEST	ALASKA	PACIFIC * ISLANDS	
SHRIMP											
WEIGHT	2,093	76	26,120	14,870	180,394	264,400	264	3,007	16,819		243.6
VALUE	245	28	10,137	4,755	66,160	66,160	28	298	757		82.4
SALMON											
WEIGHT	208						4,254	47,708	274,844		326.8
VALUE	161						2,374	14,475	48,274		65.1
OYSTERS											
WEIGHT	57	1,348	20,869	4,075	<1	19,154	376	8,788	2		54.6
VALUE	114	2,055	16,249	1,508	<1	5,711	105	2,123	2		27.8
CRABS											
WEIGHT	2,043	11,507	84,416	37,608	700	37,385	897	19,449	140,566	28	334.5
VALUE	89	794	7,436	2,061	324	2,566	231	3,500	13,729	16	30.7
LOBSTERS											
WEIGHT	23,842	6,359	44	196	5,547	61	480			8	36.4
VALUE	17,943	3,997	17	107	3,125	31	385			7	25.5
CLAMS											
WEIGHT	3,557	55,748	10,351	404		114	<1	588	89	1	70.8
VALUE	2,036	11,185	2,929	170		42	<1	329	41	1	16.0
MENHADEN											
WEIGHT	9	152,216	358,768	192,373		1,002,837					1,726.1
VALUE		2,285	5,385	2,502		16,902					27.0
TOTAL											
WEIGHT	31,602	227,254	474,468	260,676	21,118	1,259,890	6,271	79,540	432,320	37	2,793.1
VALUE	20,427	20,344	32,015	16,496	8,203	91,383	3,123	20,725	62,803	24	275.5

*CARIBBEAN, FLORIDA ONLY
PACIFIC ISLANDS, HAWAII ONLY

REFERENCE: NATIONAL ESTUARINE INVENTORY
SOURCE: U.S. DEPT. OF INTERIOR, BUREAU OF COMMERCIAL FISHERIES

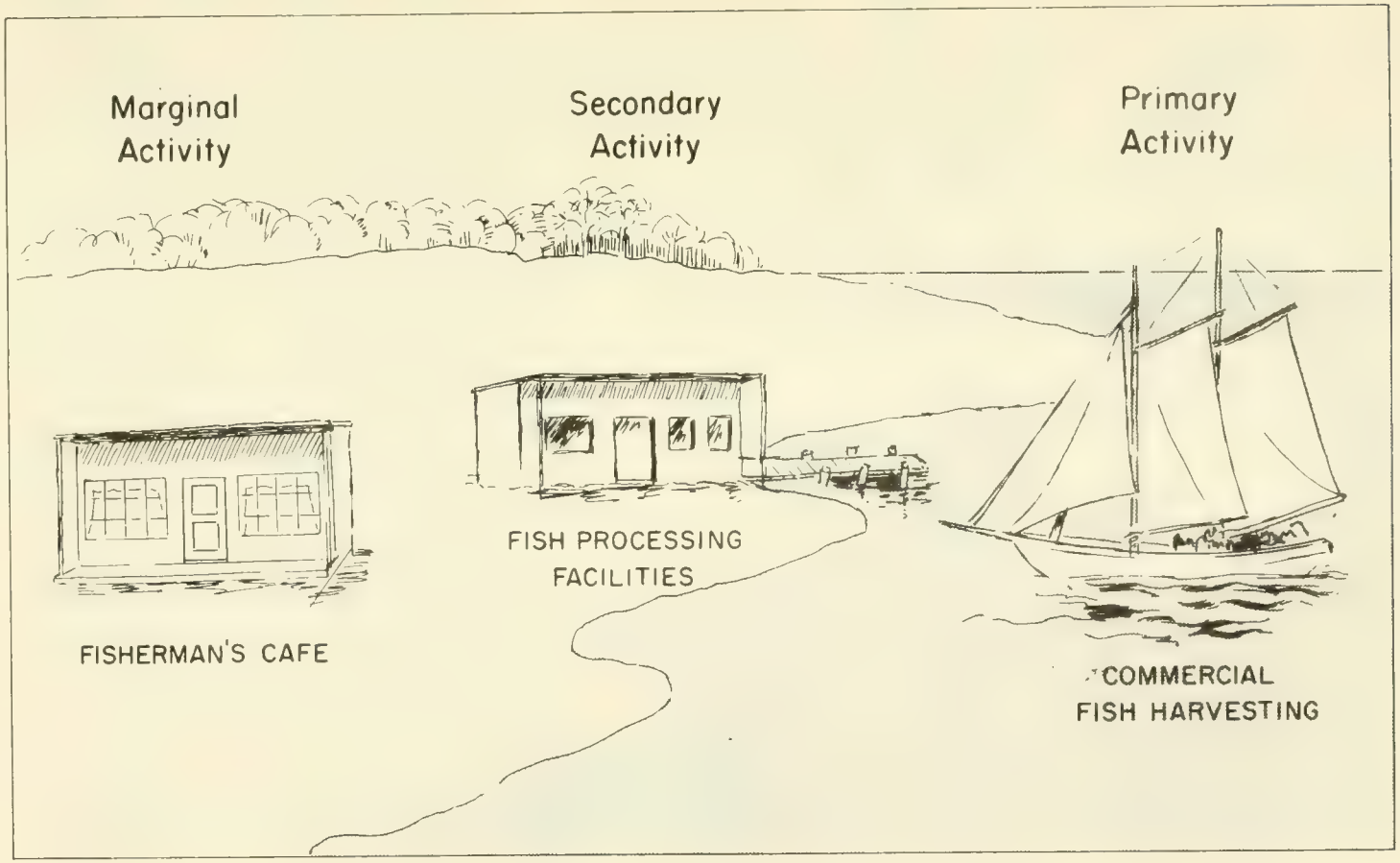
An entire complex of commerce and industry can rest upon one primary producing industry such as commercial fishing, and Figure IV.3.1 illustrates in a very simple fashion some of the more direct impacts of commercial fishing on the economy. Each time the basic product changes hands it generates economic activity and gains in value until by the time it reaches the ultimate consumer, its price may be many times what the fisherman was paid for it.

The effect of such "value multiplier" factors will be such as to make the actual values of specific commercial fisheries several times the landed values such as those given in Table IV.3.4 and Table IV.3.5.

Thus, the 438 million dollars received by United States fishermen in 1967 probably represents a total input to estuarine zone economic activity of over one billion dollars; exactly how much it is impossible to say. Case studies discussed later in this chapter assign multiplier values of about three and four to commercial fishery landing values, but the magnitudes of such multipliers depend on the structure of the local economy as well as on other factors and generalities are likely to be misleading.

Consumption of both edible and industrial fish products continues to increase, but the part of the consumption supplied by domestic fishermen continues to decrease. Imports represented 82 per cent

FIGURE IV.3.1 EXAMPLE OF ECONOMIC ACTIVITIES RELATED TO ESTUARINE RESOURCES



of the industrial fish supply and 53 per cent of the edible fish supply in 1967. A primary cause of this loss of market is the inability to compete economically with foreign fishing fleets using the most advanced technology. Aquaculture is a potential means for correcting this condition, and, as such, represents a potential estuarine use of large but indeterminate value.

The relationship of the estuarine zone and commercial fishing cannot be expressed by any simple economic index. This brief discussion shows that the importance of commercial fishing in the estuarine zone is related economically not only to estuarine habitat, but also to transportation, commerce, food processing, and aquaculture.

RECREATION

Recreation is the one major estuarine use that is directly and irretrievably related to individual people. It is a pursuit carried out strictly on an individual choice basis and has as much variety as individuals themselves have. Every estuarine system where there are people is subject to recreational use, whether it is of recreational quality or not.

When an estuarine system is of poor recreational quality, only those people who cannot afford to go elsewhere will use it. When

a system is of acceptable quality, many local people will use it and it may even attract some tourists from less-favored areas. When an estuarine system is not only of acceptable quality but has other attractions such as beautiful scenery or pleasant weather, recreation and tourism become major commercial enterprises.

Each kind of recreational use has its own economic impact. Recreational boating supports a large boatbuilding, marina, and boat repair industry. Sport fishing supports not only a certain part of the boating industries, but also a very specialized industry manufacturing and selling fishing tackle. For example, the 1965 Survey of Fishing and Hunting shows that salt-water anglers spent $800 million dollars in that year. Sightseeing and swimming support motel and restaurant services in the favored areas, as do other overnight recreational activities. Table IV.2.3 gives the advantages and disadvantages of several indices of recreational economic impact; as this table shows, there is no single satisfactory index for showing the importance of the estuarine zone in recreation, or vice versa.

In many cases the economic value of recreation may depend upon the total economic structure of a particular estuarine system. For example, the Biscayne Bay area in Florida is oriented toward

the recreational pursuits of the vacationing tourist; the useful indices of recreational activity here would be motel, hotel, charter boat, and marina revenues. The shoreline of the Chesapeake Bay in Maryland, in contrast, is almost entirely oriented toward private residences or commercial marinas catering to the regional resident, who needs permanent boat mooring facilities.

The significant indices of recreational activity here would be boat sales and repairs, marina revenues, and waterfront property values.

Attempts at the quantification of overall recreational economic values are not yet well-developed. The user-day recreation benefits approach has been used in some federal waterway and reservoir projects, but has been used in the estuarine system only in an analysis of fisheries and recreation in San Francisco Bay. Net benefits for general recreation activities, by this method, range from $0.50 to $1.50 per day. Specific forms of recreation may have higher values.

Applying such a figure to the population of the coastal counties suggests that the value of the recreational resource of the estuarine zone is about 300 million dollars if each person has about five days of recreational use. Such an estimate would include only local use and no multiplier values and might therefore be regarded as minimum value of the entire value of the entire estuarine recreation resource.

The major problems in defining the economic values of recreation in the estuarine zone lie in the facts that recreation itself is not an easily defined commodity nor can it be isolated from other economic activities such as transportation, food and lodging services, and equipment manufacturing.

COMMERCIAL NAVIGATION AND NATIONAL DEFENSE

The economic value of commercial navigation is easier to establish than the value of any other activity. Even here, however, there is impact of this use on other estuarine uses, and the estimates of economic value are not complete. Estimates of the economic value of commercial navigation are based on the direct revenue to the port of handling a ton of cargo, generally $16 to $20. Such estimates lead to a total value of the estuarine resource of $4.7 billion annually for cargo revenues alone,

without multiplier values. An additional economic value of $10 billion annually in salaries and wages has been estimated for the eleven major ports listed in Table IV.2.5.

These estimates do not show the impact of commercial navigation on land transportation, shoreline development, or the manufacturing industries. Without the deep, safe harbors commercial navigation could not exist on a large scale, and without commercial navigation the great cities around these harbors would not have developed.

Deep-water harbors are essential elements of the national defense system. Furthermore, the location of these deep-water ports has influenced the location of other defense installations as well as the industrial complexes necessary for the logistical support of the defense effort.

The cost of the national defense effort in the estuarine zone for 1967 is estimated at about $900 million, exclusive of pay and allowances for shore-based Navy and Marine Corps personnel. The economic impact of national defense activity overlaps into all other estuarine zone uses because of the massive payrolls associated with it. This impact is centered in the areas with major defense installations, as will be shown in the case studies

presented later in this chapter.

WASTE DISPOSAL

The waters of the estuarine zone have received wastes from the people and industries on their shores ever since the first cities were founded. The economic benefit in the use of estuarine waters for waste disposal has been fully utilized by nearly all industries and communities in the estuarine zone, and only the tremendous capacity of estuarine waters to absorb and remove waste materials has kept the estuarine zone from suffering severe damage from such waste discharges.

All other uses of the estuarine zone result in the need to dispose of some waste products, and the general practice has been merely to dump them into the water and forget them. Chapter 5 discusses the sources and nature of pollutional materials and activities, and how this use of estuarine zone waters can affect other uses.

The economic benefit of this estuarine use is a real one and it must be considered along with other established uses of the estuarine zone. This benefit can be calculated in terms of the difference between the cost of an advanced degree of waste treatment needed when the waste assimilation capacity of the estuarine

system is fully utilized.

No overall estimate of the value of this use of the estuarine resource is possible because the level of treatment necessary in any particular case depends on many local factors.

While the use of estuarine waters for waste disposal may not be aesthetically appealing, it is an existing estuarine use with which other uses must compete, and it should be considered along with them in the overall economic evaluation of estuarine uses.

SECTION 3. REVIEWS OF CASE STUDIES OF USES OF THE ESTUARINE ENVIRONMENT

The preceding section discussed separately some important estuarine uses and showed how the calculable economic estimates fell short of showing the actual value of each use. This Section describes several estuarine systems as socioeconomic environments to show how the use balance in each may differ from the others and how one use may dominate all others.

Almost all estuarine systems have either a multiplicity of uses at the present time or such uses are available in the system. Estuaries presently support such varied uses as military berthing and associated activities, commercial port facilities, shipping channels, industrial uses, commercial fisheries, sport fishing, recreation, wildlife habitat, and purely aesthetic purposes. In most estuaries one or two of the uses predominate while the others take minor roles.

It is, however, important to understand that estuarine uses are not mutually exclusive and that with sufficient planning and caution, these uses can exist in harmony with one another. In fact, in order to receive the maximum return from a natural resource such as an estuary, all of the uses of the specialized environment should be developed to the maximum with the detrimental uses minimized.

Minimizing detrimental uses does not, in most cases, mean that the major activity must be stopped. Rather, it means that for most

uses only the harmful extent of such uses must be stopped or restricted. For example, sanitary wastes discharged from ships may be a harmful side effect of shipping that must be curtailed. There is no need to conclude, however, that shipping must be stopped. Similarly, water skiing or boat racing may be harmful to sport fishing. However, a simple zoning of certain areas for use of sport fishermen and not for high speed boating or water skiing allows the use of an estuary for all these pursuits.

At the present time, the major uses of estuaries, in terms of gross monetary return are: military use, shipping, and industrial activities. These uses are, of course, historical and do not necessarily reflect the uses that would be made of the estuary under today's conditions or future conditions, if each use were to compete for the water use at the same time. In other words, historical use has brought about the present use imbalance in many estuarine systems. However, given the opportunity to develop, other uses might attain equal importance economically while contributing important social benefits.

Estuaries at the present time represent underdeveloped natural resources that are important to the social as well as the economic well-being of the Nation. Although lack of understanding of the dynamics of an estuary and the inability to foresee the coming of age of an industrial economy, with its resultant increase in leisure time, may have combined to allow undesirable exploitation

of certain estuaries, such exploitation need not be allowed to continue.

Based on present trends and demands, there is little doubt that there will be a tremendous need for estuarine uses other than for military, shipping, and industrial uses. That is, if the facilities are available for recreation, sports, or aesthetic enjoyment, they will be used and used to great advantage from an economic standpoint as well as a social standpoint. Also, some commercial fishery ventures may again become not only feasible but profitable if the detrimental uses of estuaries are curtailed.

NARRAGANSETT BAY
(IV-3-1)

The Narragansett Bay system in Rhode Island and Massachusetts is an estuary of approximately 170 square miles with a total shoreline of approximately 240 miles. Except for normal shoaling towards shore, there are only very limited areas where the water depth is less than six feet at mean low tide. Passages between the islands have sufficient depths for large ships--channels need only be dredged where they enter the Taunton and Providence Rivers. Because of the islands in the Bay and the irregular coast, Narragansett Bay has a long shoreline with coves and embayments that are protected from the wave effects of major storms. The tidal range is a moderate 3-4 feet but a favorable cross section to length ratio of the basin helps to ensure reasonably good

flushing. Figure IV.3.2 is a map of the Bay.

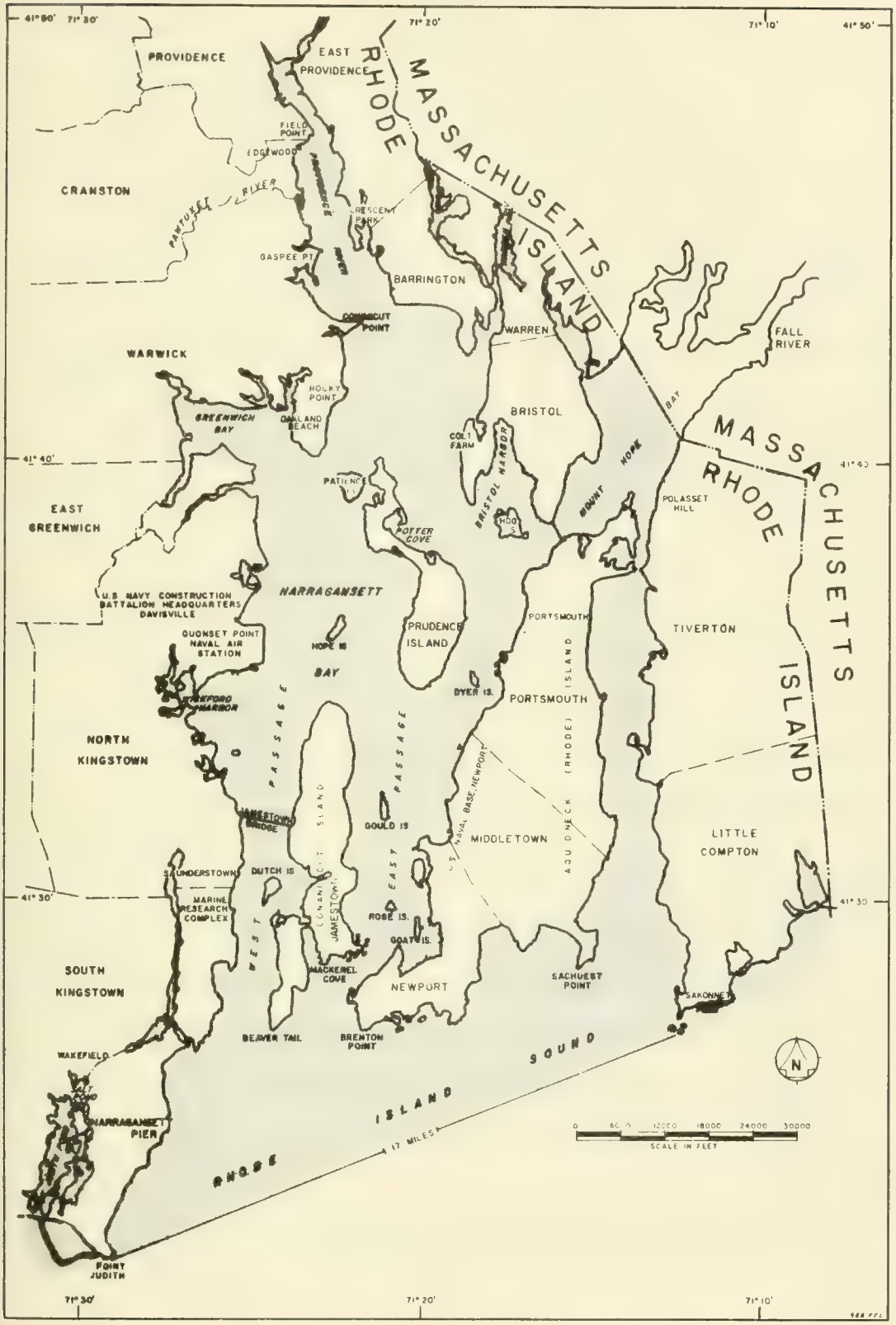
The population of Rhode Island is mainly clustered about the shores of Narragansett Bay. A special census in 1965 enumerated the total at 892,709 of which some 69 percent resided in towns and cities touching the bay. The long term migration of the population appears in a gradual movement from the upper bay towns to the lower bay towns. In the total bay area, there are 69,160 areas of developed land and 115,039 areas of land with development potential. Table IV.3.6 shows the distribution of developed land.

TABLE IV.3.6
Percent of Use by Category of
Developed Land

Narragansett Bay, Rhode Island

USE	Proportion in Percent of Developed Land	
	URBAN	RURAL
Residential	41.2	42.4
Industrial-Commercial	12.3	9.8
Governments, Institutions, or Public Utilities	15.4	20.8
Recreational	9.9	9.3
Roads and Highways	21.2	17.7

FIGURE IV.3.2 NARRAGANSET BAY AND VICINITY



From Colonial times, when perhaps the more important economic activities were purely Bay-oriented (e.g., fishing and foreign trade), industry and trade has clustered about the Bay and its tributaries following the growth of population in these areas and the concurrent growth of a pool of skilled labor. Within the total socioeconomic environment of the area, seven estuarine-dependent product-producing areas are examined to show some of the methods involved in deriving a value for a given use. The categories include commercial fisheries, defense establishments, recreation, Bay transportation, marine-oriented industry and commerce, research and education, and waste disposal.

Table IV.3.7 shows the production, value and productivity of the Narragansett Bay fisheries for 1939 and 1965. In order to illustrate the former importance of a species, the oyster is included although it is no longer commercially important.

There has been a reversal in the relative importance of the fin fisheries and shellfisheries over the 25-year period due partially to the decline in the oyster fishery resulting from the disappearance of the wild oyster from Narragansett Bay for unknown reasons. Improvement in finfishing methods together with a lack of improvement in shellfishing methods have also contributed to this reversal.

TABLE IV.3.7

Commercial Fisheries of Narragansett Bay

	Finfish	Shellfish*		
		Oysters	Clams	Total
-1939-				
Fishermen	101	--	--	924
Catch, lbs.	4,022,900	2,313,500	2,197,900	5,147,200
Catch, $	122,808	399,100	250,600	774,134
Catch Per Fisherman, lbs.	38,830	--	--	5,571
Gross Value Per Fisherman, $	1,216	--	--	838
Average Annual Price, $/lb.	.035	--	--	.15
-1965-				
Fishermen	718	--	--	1,437
Catch, lbs.	9,809,700	11,500	2,297,300	2,695,000
Catch, $	838,202	14,100	1.062,700	1,372,653
Catch Per Fisherman, lbs.	85,302	--	--	1,875
Gross Value Per Fisherman, $	7,263	--	--	.955
Average Annual Price, $/lb.	.085	--	--	.509

*Meat weight only, except for lobsters which are live weight

One of the most significant features shown in this table is that earnings per fisherman from shellfish changed only slightly from 1939 to 1965, while earnings from finfish increased six times, all during a period when shellfish prices increased much more than finfish prices. This suggests that the shellfishery in Narragansett Bay is unable to compete economically with the finfishery and that it may be declining as a significant resource use.

DEFENSE ESTABLISHMENTS

One of the oldest uses of Narraganset Bay, and certainly the most important today from the point of expenditures, is the role of the Bay in the National military establishments. The strategic location and excellent harbor led to its early use as a base for Naval operations, and, with accommodation to the changes and innovations of modern warfare, so it remains today. Located at Newport, where important fleet units and academic activities are based, and at Quonset Point (North Kingstown), the United States Navy in Rhode Island is the largest single employer in the State and produces the highest level of dollar output direct attributable to the Bay.

About 90 percent of the U.S. Navy expenditures in the Narragansett Bay area are paid as wages and salaries to civilian and Military personnel. Substantial sums are also expended annually on contract

construction, maintenance and repair, utilities and purchases from local merchants. Finally, direct payments are made by the Federal Government (in lieu of taxes) to school districts enrolling children of military personnel.

Table IV.3.8 shows the contribution of the Naval establishment to the Bay economy and the growth of this contribution between 1963 and 1967.

In spite of the size of the Navy operation, there are only two areas of conflict between the military and other Bay uses. These are problems created by sewage disposal and problems from oil pollution. The shore installations of the Navy in Narragansett Bay are either served by sewage disposal facilities on a par with those in the surrounding communities or share, on a user-charge basis, with surrounding communities in disposal facilities which meet the approval of the Rhode Island State Board of Health. The sewage pollution problems that do exist are associated with the discharge of untreated wastes from oceangoing vessels. The Bay is home port for about 70 ocean going vessels and numerous other smaller craft. Few vessels have sewage treatment facilities aboard.

TABLE IV.3.8
Spending by the United States Navy in the
Narragansett Bay, Rhode Island Area, 1963-1967

Item	Years	
	1963	1967
Wages and Salaries to Civilan and Military Personnel (1)	Total Only	197,274,605
Local Purchases of Goods and Services (2)	" "	10,516,557
Contractural Construction Maintenance and Repair and Utilities (3)	" "	5,163,502
Federal Aid to Impacted School Districts in R.I. (4)	" "	2,853,720
TOTAL	$124,240,000	$215,808,384

(1) May be somewhat inflated because 1967 report does not separate out fleet military personnel who may have been paid elsewhere. Sum also includes allowance to dependents.

(2) Includes only those sums specifically mentioned as being spent locally.

(3) Based on contracts awarded during the year, estimating most or all small maintenance and report contracts. All assumed to be with local contractors.

(4) School year 1967-68.

Recreation

Six categories of activity are considered: swimming, boating, sportfishing, waterfowl hunting, scuba and skin diving, and summer residences.

Swimming

There are state, municipal, and private beaches on the 31 miles of sandy beach in Narragansett Bay. Table IV.3.9 shows the estimated maintenance costs and intensity of use for each kind of beach.

TABLE IV.3.9
Swimming Beach Use in Narragansett Bay, 1967

	State	Municipal	Private*	Total
Length of Beach, Feet	3,829	16,150	-----	19,979
Annual Expenditure by owner, $	100,741	164,979	119,574	385,294
User-days	624,000	642,000	465,000	1,731,000
Expenditure per User-day, $	.16	.26	-----	.22
User-days per foot of beach	163	40	-----	87

*Value estimated from municipal

The estimated annual maintenance cost of $385,000 is the only economic indicator available to show the value of this type of recreational use.

Public beach use in Narragansett Bay appears to be heavily concentrated in a few State beaches, and other beaches seem to have adequate space to support the swimming demand.

Boating

Estuaries favor recreational boating because of the relatively protected waters and variety of activities possible. Narragansett Bay, with its deep embayment and many protected waterways has been a historically prominent recreational boating area. Not all boats are registered, so that the total numbers of boats actually using the estuarine system cannot be obtained directly. In 1965, however, 10,175 recreational boats were registered in the State of Rhode Island. In addition many out-of-state boats use the Bay.

Surveys of boat owners as well as boatyard and marina operators give an estimate of annual expenditures for boating of $5.2 million dollars based on boat operating and maintenance costs. Table IV.3.10 shows the estimated participation in boating in Narragansett Bay. This number of user-days appears excessive since it would require 25 trips of each 15,000 boats with at least five persons on each trip; it is included to show the difficulties of assembling data to establish economic values for recreational pursuits.

TABLE IV.3.10
Estimated Participation in Boating-Narragansett Bay
1965

	Percent	Persons	Days Per Person	User Days
Boating	28	168,000	9.5	1,596,000
Sailing	5	30,000	11.5	345,000
TOTAL	33	198,000	----	1,941,000

Based on estimates of a 600,000 population over 12 years of age in Rhode Island.

Source: "The 1965 Survey of Outdoor Recreation," Bureau of Outdoor Recreation, U. S. Department of the Interior, October, 1967 pp 45-52

Sport Fishing

Saltwater sport fishing is an extremely popular use of Narragansett Bay and adjacent waters. About thirty-eight percent of boating time on Narragansett Bay and adjacent waters is allocated to sport fishing, and there is considerable fishing from shore. This takes place primarily in four types of areas: from bridges that cross streams feeding into the Bay or connecting the Bay with other smaller estuaries; from the breakwaters on piers that jut out into Bay; along the rocky shoreline in the southern part of the Bay; and the sandy beaches at the end of the swimming season which coincides with the fall runs of Bluefish and Striped Bass.

It is not possible to estimate the total expenditures for sport fishermen in Rhode Island, for no reliable data are available from which to estimate their number. What is significant, however, is that a great many people engage in it, and that it is a relatively low-cost outdoors activity within the means of many.

Waterfowl Hunting

In addition to commercial fisheries, Narragansett Bay is an important feeding and resting area for migratory waterfowl. The Bay is considered to be a relatively large unit of high quality migration and wintering habitat. The major species using the area include many highly desirable game birds.

No formal data are available on the number of hunting trips that were made annually by each purchaser of waterfowl stamps. Based on data from other northeastern States and considering the waterfowl counts and hunting regulations, it is estimated that each hunter made about 3.5 trips per year on the average. Bag checks by Rhode Island conservation officers indicate an average kill of 0.56 birds per trip. For 1968 it is calculated that 2,507 hunters making 8,774 trips shot a total of 4,900 birds.

Skin and Scuba Diving

The popularity of this activity in Narragansett Bay has been greatly enhanced by the natural advantages which are not present in the adjacent coastal areas. The Bay's ocean-front shoreline

has some access ways which permit diving and spearfishing directly from shore without a boat. Most sport diving is conducted in waters shallower than 100 feet, and much of this area is within swimming distance of the shore. The Bay also attracts many sport divers from outside the State.

Seasonal Residences

The last category of recreational use is that of seasonal residences. Seasonal residences are defined as those houses occupied generally for recreational purposes for a part of the year. In Rhode Island, most, if not all, seasonal residences are summer residences. Based on building permits for 1961-1965, it is estimated that in property tax revenue alone, summer property approaches an annual value of $1,000,000. Although the presence of summer residents increases the municipal service loads, a significant absence here is provision for educational services, which generally comprise about 70 percent of municipal costs. Also the expenditures of the part-time residences stimulate employment and income of these towns. Accordingly, the total income resulting from the inflow of persons in seasonal residences in the Bay area during the summer months is much greater than the costs incurred by municipalities in providing services to such seasonal residences.

If it is assumed that five percent of the investment in property is expended annually to cover repairs, maintenance, and insurance, and

if it is further assumed that the total assessed value of the Bay summer property represents a 70 percent of the actual investment, then the total assessment of $27,418,059 would represent an investment of $39,168,600 with annual expenses of $1,958,430. Adding the expenses to the tax revenues gives an estimated annual net addition to the area of $2,870,875.

BAY TRANSPORTATION

Narragansett Bay is both an obstacle to and an avenue of commerce. The trans-state movement of people and goods is blocked by the same body of water that serves as a natural well-sheltered roadway for water-borne commerce. However, the income, employment, and expenditures generated in construction, operation, and maintenance of ocean port facilities, bridges, and ferry facilities, justify the inclusion of transportation as an economic factor.

The Port of Providence is Rhode Island's major port and ranks third in overall importance for The New England States. The economic impact of the Port can be measured through all three categories of activities - primary, secondary, and marginal (see Figure IV.3.1). Table IV.3.11 shows estimates of economic impact of various commodities passing through the Port and multiplier factors from a nationwide study of the Maritime Administration.

TABLE IV.3.11
Estimates of Economic Impact of Various Commodity Types Passing Through the Port of Providence, Rhode Island, 1968

Type of Cargo	Volume[1] (Short Tons)	Income Production[2] Per Ton ($)	Total Impact ($)
General	509,353[3]	18.46	9,402,656
Tanker (Crude or refined)	8,280,954	4.38	36,270,579
Coal	416,391	3.02	1,257,501
Total Economic Impact			46,930,736

Computed from--

1/ Waterborne Commerce of the United States Calendar Year 1966, Op, Cit., P. 26.

2/ From Correspondence with Chief, Division of Ports and Systems, Office of Maritime Promotion, Maritime Administration, U. S. Dept. of Commerce, dated September 27, 1968.

3/ Includes: 156,611 Short Tons of Iron and Steel Scrap
183,506 Short Tons of Building Cement

Table IV.3.12 shows the construction of the Port in terms of marine-related employment. This Table emphasizes the importance of the marginal activities.

The value of port improvement in facilities and navigational aids must also be considered. Where cargo facilities are concerned, past expenditures in the Port of Providence may be considered normal, given the size of the port and the complex of facilities for general

TABLE IV.3.12

Number of Firms, Average Annual Employment, and Total Wages & Salaries for 1965, Marine Related Occupations in Rhode Island (Covered Employment)

	Number of Firms	Average Employment	Total Wages ($)
Deep Sea Foreign Transportation	2	3	5,252
Deep Sea Domestic Transportation	1	7	65,184
Local Water Transportation (Ferries, Lighterage, Towing and Tugboat Service, other NEC.)	4	41[2]	481,880
Services Incidental to Water Transportation (Piers and Docks, Stevedoring, Water Transportation Services NEC.)	36	248	1,183,772
TOTALS	43	299	1,736,088

Source: Records of the Rhode Island Department of Employment Security

2/Includes Jamestown Ferry Operation (Approximately 30 employees $400,000 annual wages)

or specialized cargo handling. Based on an estimated straight line depreciation over a 17 year period, the average addition to the value of the Port is approximately $235,000 annually.

The value of channel improvements is more difficult to assess. With expenditures totaling only 4 million over the lifetime of the various rivers and harbors projects up to 1963, this amount may largely be written off. In essence, this assumes the income effects of these expenditures do not significantly add to the value of the Port. On the other hand, the much greater amount of investment in 1967, a 14.3 million-dollar dredging project over a shorter period of time, will affect the economy of the port community. Since this dredging is to enable the port to handle the newer deeper draft vessels, it is necessary to prevent port obsolescence. Again, using a 50-year straight-line depreciation an average annual charge would amount to $268,000.

In addition to the commercial shipping aspects of transportation, the impact of toll bridges must be considered. There are three toll bridges, the Jamestown bridge from North Kingston to Connecticut Island, the Mount Hope Bridge from Bristol to Portsmouth, and the Newport-Jamestown Bridge, which will replace the ferry boats. The Jamestown Bridge will become toll free in 1969 when its bonds are redeemed. The Mount Hope was built in 1929 and its outstanding bonds were retired in 1964. Tolls will continue to be collected until the Newport-Jamestown bridge is paid off. The Newport-Jamestown Bridge is scheduled to open in 1969. The Bridge is being built at an estimated cost of $60 million.

Table IV.3.13 shows a resume of the value of transportation to the Narragansett Bay area.

TABLE IV.3.13
Annual Dollar Impact of Transportation
Narragansett Bay

ITEM	IMPACT ($)
Port of Providence	47,200,000
Jamestown Ferry	740,000[1]
The Bridges	
Jamestown-North Kingston	233,000
Mount Hope	190,000
Newport-Jamestown	1,200,000[2]
Total Impact	49,563,000

1/ Discontinued after 1969

2/ Based on straight line depreciation of 50-year amortization period.

Marine-Oriented Industry and Commerce

A survey conducted in 1965-1966 showed 75 marine-oriented firms located around Narragansett Bay in addition to marinas and boatyards. The firms are involved in such activities as ship and boat building, marine electronics, sail making, and fishnet construction. At the

time of the survey, these firms employed 4,251 people and had annual cash flows of $60,006,000. The revenue break down is shown in Table IV.3.14.

TABLE IV.3.14
Cash Flow for Marine-Oriented Industry and Commerce
Narragansett Bay 1965-1966

ITEM	AMOUNT $
Purchases from Local Marine Firms	1,289,229
Purchases from Local Non-Marine Firms	4,742,454
Wages, Salaries, Interest, Profit, and Rent	39,031,502
Local Taxes	210,921
Federal Taxes and Purchases Outside Area	14,731,894
Total	60,006,000

Research and Education

The area around Narragansett Bay is the base for considerable research and education in the marine sciences. These are primarily State and Federal programs even though some education and research activity take place in marine-oriented commercial firms. The investment in and expenditure for marine-oriented educational activities in the Bay area is steadily expanding. On a dollar ranking basis, the Navy is first with various programs at the University of Rhode

Island closely following. For research the same situation exists insofar as growth and dollar ranking. Table IV.3.15 gives a summary of estimated expenditures on research and education.

Marine-oriented research and educational activities on the Narragansett Bay area have little conflict with other uses of the Bay. They exact no particular social costs in the form of unfavorable effects on the Bay environment and are income producing. Areas of greatest economic impact are under supervision of the military establishment and are subject to the changing dictates of national military policies.

Waste Disposal

It is estimated that approximately 150 million gallons per day (mgd) of liquid wastes flow into Narragansett Bay through municipal sewer systems or treatment plants. At the beginning of 1969, 20 percent of these wastes received primary treatment, 70 percent received secondary, and 1 percent received tertiary treatment. The remaining undetermined amount of wastes are either discharged untreated into the Bay or to individual treatment systems such as septic tanks where the effluent may eventually seep or leak into the Bay.

The tidal action in the Bay and the Bay itself are in fact part of the waste disposal process. With two exceptions -- harvesting of shellfish and to a lesser degree contact recreation -- this

TABLE IV.3.15
Estimates for Expenditures for Research and Education on or Connected with Narragansett Bay Rhode Island, 1967-68

ACTIVITY	RESEARCH AND EDUCATION ($)
U. S. Navy	
Naval Schools Command Naval Destroyer School Naval War College	17,328,879
Naval Underwater Weapons Research and Engineering Station	13,146,662
U.R.I.	
Graduate School of Oceanography	2,322,000
Department of Fisheries and Marine Technology	150,000
Other U.R.I.1/	513,000
Department of Ocean Engineering	375,000
Miscellaneous	
Narragansett Marine Gamefish Laboratory (USDI)	120,600
Northeast Marine Health Sciences Laboratory (USPHS)	560,000
National Marine Water Quality Laboratory (USDI)	786,000
R.I. State Atomic Reactor	222,694
R.I. Marine Fisheries Station	186,000
TOTAL	35,710,835

1/ Includes expenditures under the Sea - Grant Program and marine activities not elsewhere classified.

use of the Bay for waste assimilation is compatible with other uses at the existing levels of waste treatment.

The capability of the Bay to assimilate waste products is a valuable economic asset. Its worth can be estimated either in terms of the increased value of the system for other uses or in terms of increased costs for waste treatment if the Bay could not be used for this purpose.

The only real economic damage to Bay resources by waste disposal is the prohibition of shellfish harvesting in certain areas. This is a damage to the commercial shellfish industry rather than to the shellfish themselves since the closures are a matter of public health considerations and not habitat damage. If the areas presently barred to commercial shellfishing were opened, the value of the current commercial crop might increase by as much as one million dollars, assuming that there is this much additional economic demand for the product.

If the Bay could not be used for disposal of partly treated wastes it would be necessary to dispose of them to the ocean or else provide advanced waste treatment. Based on the alternative costs of these two disposal methods, the waste assimilation capacity of Narrangansett Bay has an annual economic value of six to eight million dollars.

Total Economic Value of Narragansett Bay

Table IV.3.16 summarizes annual economic activity caused by Narragansett Bay, Rhode Island.

TABLE IV.3.16
Estimated Economic Activity and Personal Income Generated by Primary Expenditures Associated with Narragansett Bay, Rhode Island 1967-68[1]

Activity	Economic Activity Generated[1]				
	Primary Expenditures ($)	Multi-Plier	Total ($)	Multi-Plier	Personal Income ($)
U.S. Navy	215,808,384	2.73	589,156,888	1.22	263,286,228
Marine Industry	60,006,000	2.37	142,214,220	.95	57,005,700
Transportation	49,563,000	1.00	49,563,000[2]	.64	31,720,320
Waste Disposal	6,200,000	1.69	10,478,000	1.29	7,998,000
Research & Education	5,235,294	1.95	10,208,823	.62	3,245,882
Boating (Services)	3,815,788	2.76	10,531,574	.94	3,586,840
Summer Housing	2,870,875	2.35	6,746,556	.78	2,239,282
Commercial Fishing	2,207,855	2.96	6,535,250	1.18	2,605,268
Swimming	385,294	2.68	1,032,587	.96	369,882
Total	346,092,490		826,466,898		372,057,402

1 For multipliers see: Rorholm, Lampe, Marshall, and Farrell "Economic Impact of Marine Oriented Activities -- A study of the Southern New England Marine Region." Economics of Marine Resources No. 7, University of Rhode Island, Kingston (1967).
2 The "primary" figure here is based on a multiplier value, hence no additional multiplier effect is present.
3 The "primary expenditure" here is actually an opportunity cost (see the appropriate section). The multiplier that has been used is that computed for "Households" since the saving occurs in household expenditures.

The accounting is incomplete in the sense that no attempt has been made to include imputed "values" or expenditures per user-days for various recreational activities, notably swimming, hunting, skin diving, and spearfishing. The expenditures incurred in these activities were not included, for in none of the four cases were

not included, for in none of the four cases were both expenditures per participant and the numbers of participants known. Also it was not possible to derive adequate estimates of the value the Bay contributes to the people of Rhode Island through its effect on environmental quality. This includes air temperature modification, open scenic space, and open space for low land aircraft approach and takeoff. These features, which have been omitted from the calculations, are unquestionably very valuable.

Spending generates income and further spending. Multipliers developed in an earlier study have been used to estimate the extent to which the $346 million primary expenditure generates further economic activity and personal income in the area. It is estimated that primary expenditures generate a total transaction of $826,466,898 of which over $372 million is personal income in the form of wages, salaries, profit, interest and rent. The latter figure may also be thought of as the local value added. The total transactions generated are about 23 percent of the Gross State Product for Rhode Island which was estimated at about $3.5 billion in 1964. The $372 million personal income is about 13 percent of total personal income in the State in 1967 which was estimated at $2.9 billion.

Narragansett Bay gives an example of an estuarine-oriented economy which has grown up in an unorganized fashion as economic and social pressures dictated. The major contributing monetary factor is the

expenditures of the U.S. Navy, which amcount for nearly two-thirds of the economic activity generated in the Narragansett Bay area. The least significant economic use is commercial fishing, accounting for less than one percent of the economic activity.

An estuary such as Narragansett Bay, through its effect on the physical environment of the surrounding area, bestows a certain value on this area. This is the only "output" of the Bay which does not require combinations of labor and capital added to the Bay itself. To be sure, it may be possible to increase this output or effect by certain man-made modifications, but since the evaluation of our environment is to a large extent subjective, one cannot always be sure that net results of man-made modifications are, in fact, positive.

There are two kinds of specific environmental effects involved:

(1) Climatic effects. Weather data indicate that the Bay lowers the mean maximum summer temperature in Providence as much as 4 degrees through the way the Bay channels the afternoon sea breezes inland from the ocean. Similarly the water gives off its stored heat at a slower rate than does the land resulting in some modification of mean low winter temperatures. This can be observed on numerous occasions when the coast will experience sleet or rain while it will be snowing and drifting some miles inland.

(2) Open Space. Open space serves a number of purposes in and around urban areas, all of which are difficult to quantify. There is no doubt, however, that the Upper Bay and Providence River North of Conimicut Point, as well as the Barrington and Warren Rivers, provide the surrounding communities with open space which they otherwise would have had to provide in the form of parks or other open areas in order to keep the kind of environmental quality now given free by these waters. The open space provided by the Bay also serves as low-level flight space for approach and take-off at the Quonset Point Naval Air Station, saving the community a great deal of noise pollution and a resultant drop in property values.

The general effect of open space on residence values has been observed frequently. It is commonly accepted that property values increase markedly as a park or other open area is approached. The same is the case as one approaches the shoreline, even if the water itself is not usable at that particular location. If higher prices are paid for property on a shore which is not suitable for either boating or swimming, then this value must be caused by the marine environment in general.

The discussion of Narragansett Bay has been almost entirely from an economic viewpoint. Such discussions are necessarily limited to calculations based on individual values, and cannot consider the value of the general marine environment. This can be established only from the attitudes of an entire community to the estuarine resource.

APALACHICOLA BAY (IV.3.2)

Apalachicola Bay, located in Florida off the Gulf of Mexico, provides a direct contrast with Narragansett Bay. This is important not only in illustrating the diversity of uses to which estuaries currently are put, but also in providing a basis for evaluating an estuary's socioeconomic situation on a different, and possibly more meaningful, basis.

Apalachicola Bay, unlike Narragansett Bay, is not a berthing place for military vessels and, accordingly, does not have the type of economy which a significant military complex engenders. Nor is the coastal estuary a commercial port of importance. Rather, studies have shown the present and potential importance of commercial fishing, recreation, and tourism to this estuary.

Commercial Fisheries

The economic base of Franklin County, Florida, the land area upon which the Bay is located, is unusually narrow. Dependence on

commercial fishing and on the processing and export of seafood from the County is so great that serious pollution would be disastrous to its inhabitants. In November 1963, for example, about 62 per cent of the employment in Franklin County was related directly or indirectly to the oyster industry. Direct employment is made up of jobs as tongers and workers in shore installations, while indirect employment consists of a variety of middleman functions related to the industry. This is only a partial view, however, of the importance of unpolluted water to the economy of Franklin County. Employment, direct and indirect, associated with other types of seafood -- to the extent that the catch is made in the Bay or outside if the Bay was the "nursery" --- and much of the employment based on tourism is attributable to adequate pollution control.

As an initial step in determining the economic value of Apalachicola Bay, value and quantity statistics have been assembled for finfish and shellfish landings.

Table IV.3.17 summarizes these figures for the four years, 1964 through 1967, for which complete data are available. Separate statistics are presented for oysters, shrimp, crabs, and finfish. Some shellfish are included with the finfish but in no year do they amount to more than one per cent of the total quantity or value figures for finfish.

TABLE IV.3.17
Fish and Shellfish Landings and Values, Apalachicola Bay, 1964 - 1967

Species	1964		1965		1966		1967	
	Catch Lbs.	Value $	Catch Lbs.	Value $	Catch Lbs.	Value $	Catch Lbs.	Value $
Oysters 1/	1,415,600	396,368	1,380,500	463,301	2,191,100	673,562	2,404,800	730,578
Shrimp 2/	704,100	129,861	202,500	52,396	271,800	75,143	138,000	35,501
Crabs 3/	552,500	38,078	935,700	51,082	610,100	30,501	675,400	36,668
Fin Fish	1,887,300	134,713	1,614,100	129,372	937,600	82,571	432,600	58,159
All Species (Total)	4,559,500	699,020	4,132,800	696,151	4,010,500	861,777	3,650,800	860,906

1/ Shucked Weight

2/ "Heads-off" Weight

3/ Live Weight

Source: Apalachicola Office, Fish and Wildlife Service, U. S. Department of the Interior

The four-year totals show a total catch of 16,353,600 pounds, valued at $3,117,854, for Apalachicola Bay. During the period, there was a significant increase in oyster landings and value accompanied, conversely, by a large decrease in shrimp catch over the period.

It should be recognized that the landings (fisherman's) value represented only a part of the total value of the fishing industry. For Franklin County (Apalachicola) oysters for example, the final value averaged four times the amount paid to the fisherman (and dependent upon the final form in which the oysters were sold, this multiple could exceed seven times the fisherman's value).

In 1967, wholesale prices of oysters fluctuated between $4.50 and $6.50 (per gallon, shucked) for standard oysters and between $5.50 and $7.50 for select oysters. The markup to truckers ranged from $1.75 to $2.00 per gallon during the year averaging $1.50 per gallon to dealers. All of the available information lends support to the conclusion that the final value of the oyster industry is about four times the fishermen's value. For 1967, this total amount would be $5,098,860.

The total value of shrimp landings in Franklin County in 1967 was $431,018. However, all the landings were not directly related to the Apalachicola River and Bay. Significantly, the shrimp caught in the Gulf areas nearest the Apalachicola River and Bay are more closely related to the estuary and it has been estimated by

oceanographers that approximately 90 per cent of all of the shrimp caught in areas close to the Bay were originally inhabitants of the estuary which served as a "nursery" for these shrimp, a reflection of the economic value of estuaries which is not always recognized.

To illustrate the commercial fishery value of the estuaries further, shrimp prices (with head off) averaged $.92 per pound in 1967. Of the final retail average of $1.30 per pound, five cents per pound represented the wholesaler's markup with the remaining thirty-three cents being received by the retailer. With the conversion factors provided by the price data it can be estimated that the total retail value of the shrimp landings attributable to the Apalachicola estuary is approximately $471,260.

Table IV.3.18 contains the projects of the annual fishery landings values attributable to the estuary. Projects are made for the years 1975, 1980, and 2000. Because oysters and shrimp are highly income elastic products, the value of their production should increase at a rate at least equal to that of the national income. This of course assumes no unusually extreme shifts in supply. A rate of four per cent has been compounded to the base years to approximate the future values of oyster and shrimp landings.

Finfish and, to a lesser extent, crabs have a much lower income elasticity. Thus, a growth rate of only two per cent has been used in extending their values forward to the years cited in the table. Again supply variation and/or changes in processing methods can affect estimates. For example, an increased use of fishery products as a source of protein for underdeveloped countries would have an impact on the demand side.

This material reinforces the contention that simple values of fishery landings are a totally inadequate measure of the "true value" of the fishery resources involved. Only by studying both the values added in production and the income generated by the income multiplier can a realistic estimate be made.

TABLE IV.3.18
PROJECTIONS OF THE ANNUAL VALUE OF APALACHICOLA ESTUARINE RELATED LANDINGS 1/

Species	1967	1975	1980	2000
Oysters	$5,098,860	$6,975,240	$8,489,602	$18,600,641
Shrimp	$ 471,260	$ 644,633	$ 784,648	$ 1,719,156
Crabs	$ 285,452	$ 334,264	$ 369,089	$ 548,639
Finfish	$ 576,981	$ 675,645	$ 746,036	$ 1,108,957
All Species	$6,432,553	$8,629,832	$10,389,375	$21,977,393

1/ Values are in terms of final retail values.

Value of Tourism and Recreation

A great deal of the economic value of clean water in Apalachicola Bay derives from its attraction to tourists. Salt and fresh water fishing, swimming, water skiing, surf boarding, boating, sunbathing, and gathering oysters along the shore are among the water-related tourist activities. Tourists from Alabama, Georgia, and North Florida are usually interested in water-related activities while residents of the South and other regions are more likely only to be passing through Franklin County. In order to estimate the proportion of water-related tourist stops on the mainland side of Apalachicola Bay, the Economics Department of Florida State University asked owners of the three largest motels in Apalachicola and Eastpoint to have all guests during July 1968 fill out a questionnaire. A total of 173 "families" comprising 480 persons filled out the questionnaire. A summary of results is shown in Table IV.3.19.

TABLE IV.3.19
Reasons Given for Tourist Interest in Franklin County, July 1968

Home	Families		
	Water-Related Interest	Passing Through	Other
North Florida	9	8	9
Other Florida	7	15	11
Alabama-Georgia	27	6	8
Other South	9	21	10
Non-South	3	25	5
Total	55	75	43

Table IV.3.19 pertains only to travelers stopping on the mainland. It is reasonable to assume that virtually all of the visitors to the offshore islands are there for "water-related" purposes and that the same is true for residents of cottages built alongside the Gulf (such as the 150 rooms in the Wilson's Beach Cottages). According to the Florida Hotel and Restaurant Commission there were 248 rooms in 18 motels and 249 rooms in the rental cottages within the County. Using the results of Table IV.3.19 for the motels, and assuming that all of the guests at the cottages are "water-related" it appears for Franklin County as a whole that about two-thirds of the tourist business is related to the estuary.

The 1967 Florida Tourist Study published by the Florida Development Commission shows 5046 automobile tourists from out-of-state with Franklin County as their destination. If arrivals by private planes, boats, and buses are added, the figure might be in the neighborhood of 5,200. Adding the estimated number that came from Florida brings the 1967 total to 7,800, of which estimated 5,200 are "water-related." The Florida Development Commission shows the average tourist stay to be 14.8 days and the average expenditure per person per day to be $17.20. Because of the lower-than-average prices of accommodations in Franklin County, average expenditures of $14 per day and average stay of 15 days appear reasonable. For 1967, this would yield a total estimate of

$1,092,000. This source of income may be expected to continue in the future at least commensurate with National or regional population increases as well as other factors. It has been projected to increase to $3,571,600 in 1975, to $5,077,020 by 1980, and to $13,377,000 by the year 2000.

Effect on Local Residents

Table IV.3.20 summarizes projections discussed ealier of the actual and potential economic benefits which may be expected with proper pollution control efforts in the Apalachicola Estuary. The main source of income in 1967 was derived from the commercial fishing industry-$4,868,118-compared with $2,799,629 accruing to total incomes of fish industry sources out of Franklin County and $1,463,280 for tourism in Franklin County for a grand total of $9,131,027. With the maintenance of satisfactory conditions in the estuary's waters, by the year 2000 it is anticipated that income from tourism will increase by several magnitudes and that a grand total in excess of $44 million will be generated.

Estimates of economic benefits to local residents indicated in Table IV.3.20 are of particular importance to the area because its present relatively low economic status indicates the local population is unable to better itself economically from pursuits other

TABLE IV.3.20
Estimated Actual and Potential Income
Generated Nationally by Clean Water In
Apalachicola Estuary

Source of Income	1967	1975	1980	2000
Local Income Generated:				
Seafood	$4,868,118	$6,493,489	$7,781,773	$16,303,655
Tourism	1,463,280	4,785,944	6,803,207	17,925,180
Total	$6,331,398	$11,279,433	$14,584,980	$34,228,835
Value Added Out of County:				
Oysters	$2,549,430	$3,487,620	$4,244,801	$9,300,321
Shrimp	16,967	23,211	28,250	61,896
Crab	95,151	111,422	123,030	182,880
Finfish	138,081	161,693	178,538	265,391
Total	$2,799,629	$3,783,946	$4,574,619	$9,810,488
Total National Contribution of Apalachicola Estuary	$9,131,027	$15,063,379	$19,159,598	$44,039,323

than those related to the estuary. However, in addition to the economic improvement which may be anticipated locally, consideration also should be given to the recreational advantages afforded by the estuary to local citizens. It is reasonable to expect that a direct relationship exists between socioeconomic level and the distance which the members of the population will travel to fill their recreational needs. That is, the lower a person's income the shorter distance he is likely to travel for purposes of recreation. Therefore, even with the increasing mobility which Americans have experienced in the last several decades, there is no question but that availability of adequate water recreational facilities near the local population is of incalculable benefit to those local citizens. These benefits can be expected to increase with the shortened workweek predicted for the future as well as the increase in economic well-being projected for the population with ready access to the Apalachicola estuary.

SAN DIEGO BAY
(IV-3-3)

The San Diego area is an example of the multiple uses and development of an estuarine system. The basic development and growth of San Diego is attributable to the military uses of its deep water estuary. However, later diversification of the economy into areas

of manufacturing, trade, tourism, and education has made the area less dependent upon a single use of the estuary. In fact, the relative value of the estuary to the entire population is shifting toward recreation and aesthetic values. Indications of the value of these recreational pursuits and aesthetic pleasures to the general populace can be found in the estimated over $2 million they are willing to spend annually to prevent pollution of the Bay by municipal sources.

The San Diego study does not provide a complete economic accounting analysis of the estuary's total value but it does give some estimates of the various components of the area's economy. Also, there are estimates of the costs of abating Bay pollution from municipal sources and estimates of the monetary benefits resulting from such pollution abatement.

Description of the Study Area

Statistical Study Areas

For purposes of the technical analysis, Bay-related land has been divided into three geographic areas. Study Area I consists of virtually all land immediately adjacent to and surrounding the Bay extending approximately four to eight miles inland from the Pacific Ocean. Study Area II lies immediately adjacent to Area I

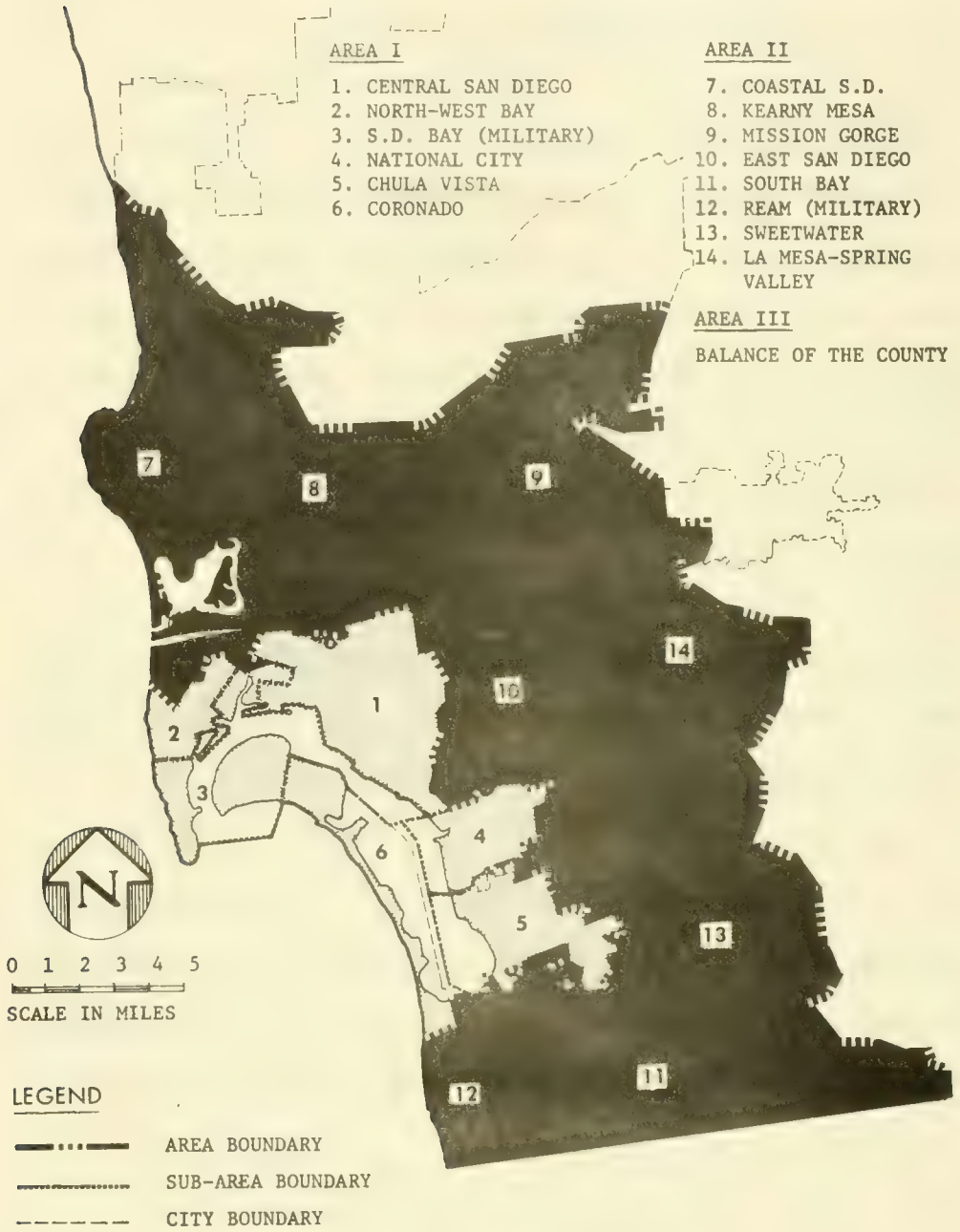
and extends approximately 15 additional miles inland. Study Area III includes the balance of the County.

General Description - San Diego County

San Diego Bay lies in the southwestern corner of the United States. It is the prime economic factor in the development of San Diego County which surrounds it. The County, which corresponds to the San Diego Standard Metropolitan Statistical Area, is bordered on the South by Mexico, on the East by Imperial County, on the North by Riverside and Orange Counties, and on the West by 70 miles of Pacific Ocean shoreline. It is approximately 80 miles wide and encompasses 4,258 square miles (Figure IV.3.3).

The entire San Diego area has many valuable natural features, but the one of greatest influence and value is San Diego Bay. The Bay is crescent-shaped, approximately 15 miles in length, varies in width from one-quarter to two and one-half miles, and has a surface area of approximately 18.5 square miles. It is protected on the west by the high ground of Point Loma and is separated from the Pacific Ocean by a narrow sand spit called the Silver Strand. North Island, once an actual island, forms the northern end of the Silver Strand.

FIGURE IV.3.3 SAN DIEGO BAY STUDY AREAS AND SUB-AREAS



San Diego Bay is one of the great natural harbors of the world. Four cities and three naval military facilities line its shoreline: the City of San Diego in the north, east, and south; National City and Chula Vista on the eastern shore south of San Diego; Coronado along the western edge of the Bay; North Island Naval Station occupying the western half of North Island; the Marine Corps Depot across the Bay to the north; and San Diego Naval Station along the northeastern shore of the Bay. The City of Imperial Beach lies just south of the Bay on the Pacific coast. Three miles north of San Diego Bay and on the coast is Mission Bay. Twenty-two years ago, Mission Bay was a tidal mud flat. Extensive development, which is still continuing, has converted it into an attractive recreational waterland.

Approximately 369,000 civilians are gainfully employed in San Diego County. The County's economy, which once depended primarily on the military and the aircraft-aerospace industries, has experienced considerable diversification. Today, other major contributors to the economy are shipbuilding, manufacturing, tourism, education, agriculture, and construction.

Government agencies comprise the largest civilian employment category in San Diego County. In 1967, 83,500 persons were in

government services. This is an increase of over 47.7 per cent since 1960. There was a similar increase in the number of persons employed in service industries. Public employment other than in the defense sector is expected to increase in proportion to the increase in the population of the County.

Today the United States Navy has modern facilities, equipment, training camps, research laboratories, and a total naval personnel of approximately 170,000 persons. An estimated 215,000 dependents of these 170,000 naval men live in San Diego County. The majority of the 100,00 shore-based military personnel are based at San Diego installations or Camp Pendleton. Additional naval personnel are based at the Ream and Miramar Naval Air Stations.

Density

Approximately 73 percent of the County's civilian population lives within 20 miles of San Diego Bay. Study Area I, adjacent to the Bay, and with less than one per cent of the County's total land area, has approximately 19 per cent of the civilian population; Study Area II, immediately adjacent to Study Area I with 6.9 per cent of the County's non-military land area, has 52 per cent of the civilian population. In other words, the population is more concentrated towards the Bay, and population density is

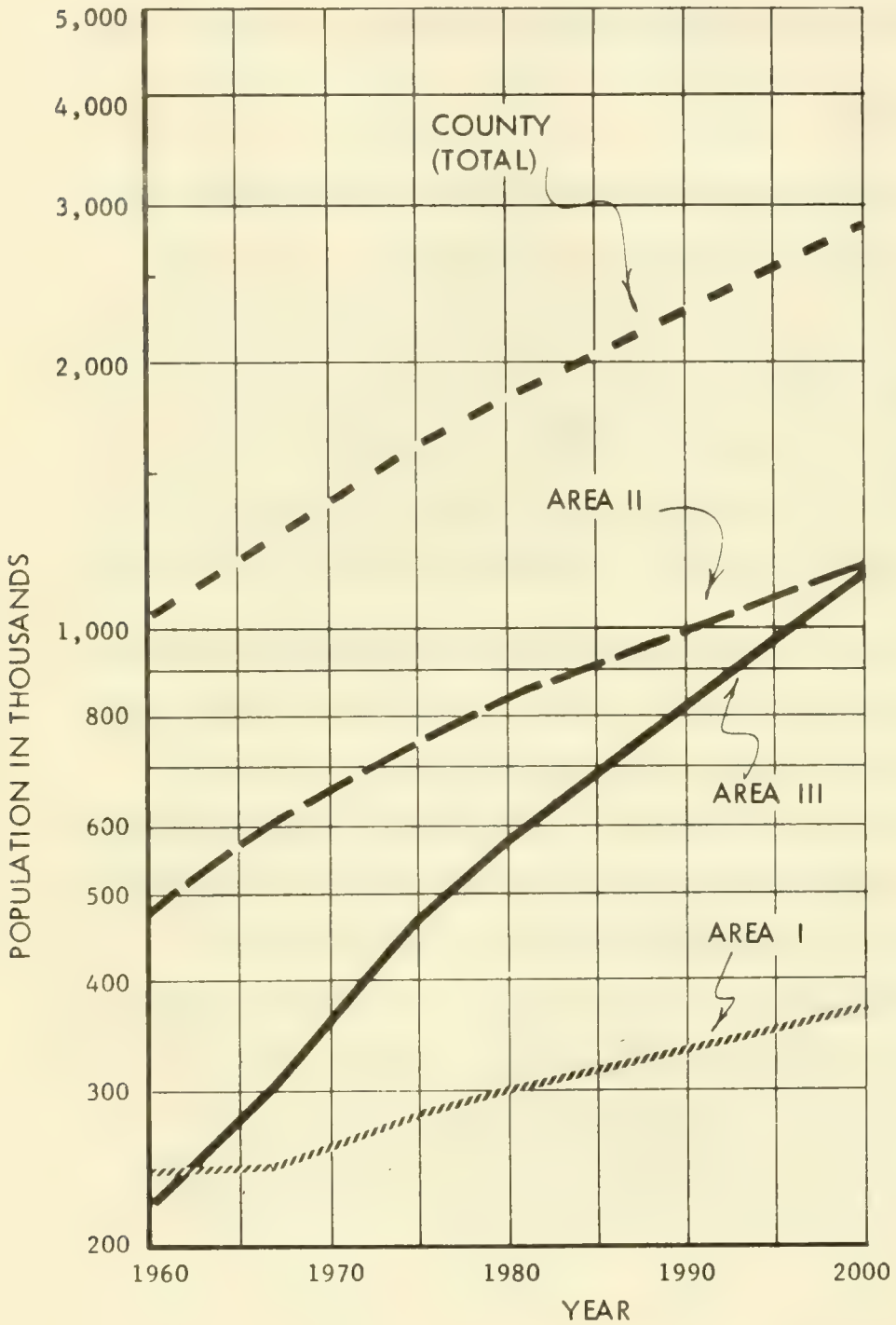
inversely proportional to the distance from the Bay. Figure IV.3.4 shows the anticipated population growth of the three areas.

Municipal Wastes

By the mid-1950's wastes discharges into San Diego Bay began to exceed the assimilative capacity of the waters. In late 1960 local voters passed a $42.5 million bond issue for the construction of new waste treatment facilities. As a result of the new facilities, no domestic wastes have been discharged to San Diego Bay since 1964. All sewage is now collected and pumped to the treatment plant from which it is discharged into the Pacific Ocean.

Table IV.3.21 shows the estimated annual dollar costs and benefits involved in the Bay clean-up. Annual costs of debt service, and operation and maintenance of the facilities range from $2.3 million in fiscal year 1967-68 to a projected $3.3 million in the year 2000. These estimated costs have been adjusted to exclude costs not borne by the local residents or those costs not exclusively associated with Bay clean-up. In other words, debt service costs associated with the Federal contribution for construction have been excluded along with those costs required whether the wastes are disposed of in the Bay or in the ocean.

FIGURE IV.3.4 SAN DIEGO COUNTY POPULATION GROWTH BY STATISTICAL AREA



PRIMARY SOURCE: REGIONAL GENERAL PLAN, SAN DIEGO COUNTY 1990.

TABLE IV.3.21
Annual Costs 1/ of and Direct Recreational Benefits Resulting From
Abatement of Municipal Pollution
San Diego Bay Clean-Up

	FY 1967-68 ($)	1975 ($)	1980 ($)	2000 ($)
Costs				
Bay Clean-Up Costs	2,312,000	2,613,000	2,848,000	3,296,000
Recreational Benefits				
Beach Activities/Swimming	2,294,000	2,837,000	3,225,000	4,776,000
Water Skiing	387,000	484,000	553,000	830,000
Sailing and Canoeing	155,000	194,000	222,000	333,000
Power Boating	2,165,000	2,763,000	3,190,000	4,899,000
Fishing & Wildlife Sports	1,000,000	1,160,000	1,274,000	1,729,000
Naval Use (amphibious and other water contact training)	NA	NA	NA	NA
TOTAL	6,001,000	7,438,000	8,464,000	12,567,000

1/ Includes debt service, operation, and maintenance. Excludes construction costs required whether wastes are discharged into the bay or the ocean, also excluded debt service costs on Federal share of construction costs.

Benefits shown in Table IV.3.21 are those directly attributable to water related recreational activities. Estimated direct recreation benefits range from $6.0 million in 1967-68, to $12.0 million in the year 2000. These benefits are restricted to recreational aspects only and do not include the impact of money spent for recreation on the associated parts of the economic system.

Economy

Military

The United States Navy and Marine Corps contributed $1.2 billion to the economy of San Diego County in 1967. This was an increase of 17 per cent over 1966. Major factors in the increase were greater military construction, the Viet Nam War buildup, and an increasing number of dependents and retired military men moving into the County. As described previously, an estimated 170,000 Naval men and Marines are stationed at military facilities in San Diego County. An estimated 173 Navy ships are based in San Diego. On an average, 90 Navy ships operate out of San Diego harbor every day. The Navy spends approximately $300 million to support these ships and the several other Naval commands in the community. For utilities (gas, electricity, water, phone) alone, the Navy spends more than $7 million every year. The Navy also employs civilian,

civil service employees, and blue collar workers who received compensation of $201.8 million in 1967. Military construction in San Diego County averages more than $20 million annually.

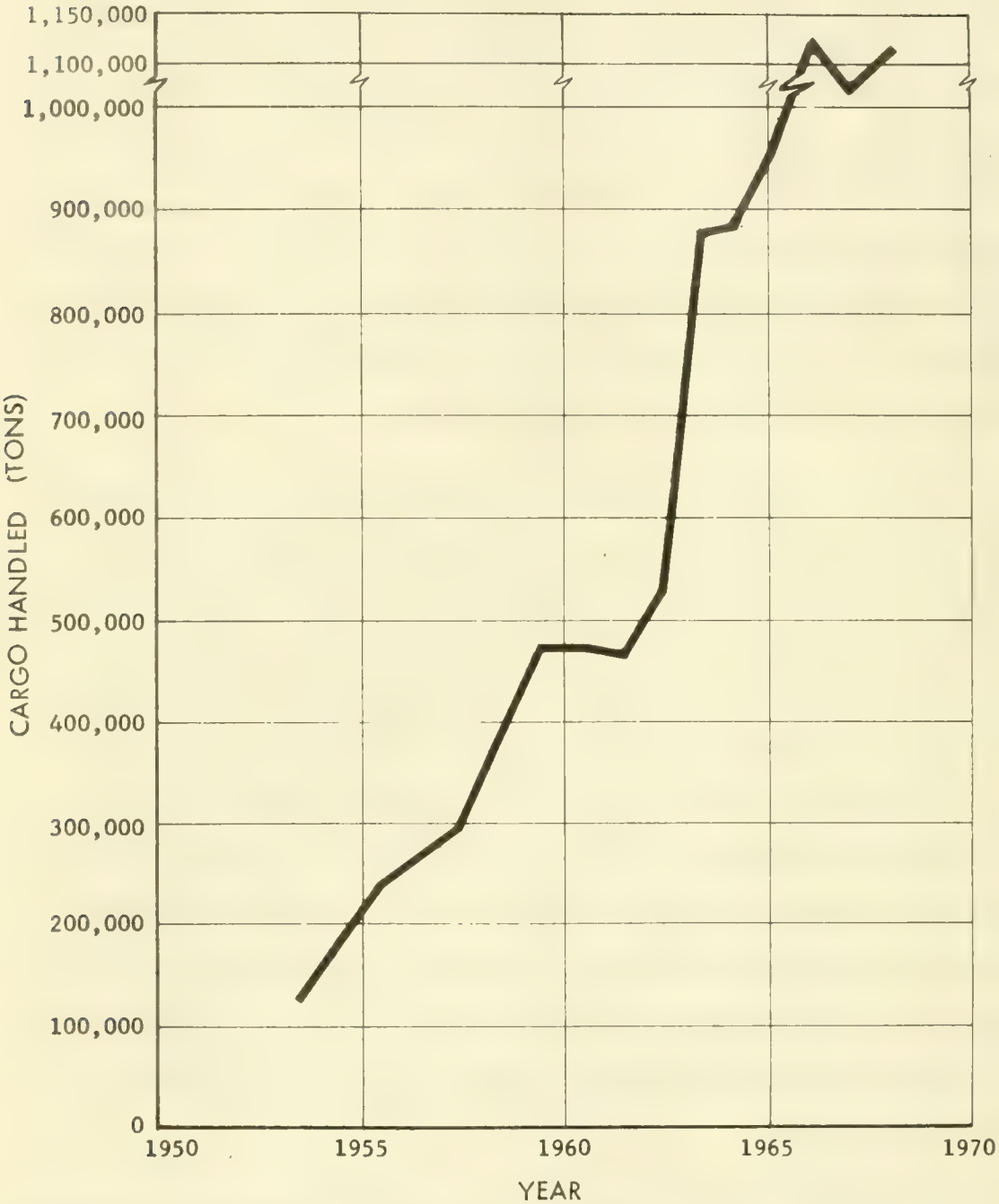
Commercial/Industrial

Maritime Commerce

The continually expanding growth (Figure IV.3.5) of the maritime industry's use of San Diego as a harbor necessitates the construction of a new terminal every 10 years.

For Fiscal Year 1967-68, Marine Terminals reported a total revenue tonnage via port of San Diego of 1,107,060 tons. The total value of cargo was $269.3 million, including bunker fuels. Inbound cargo was valued at $203.3 million, and outbound at $65.6 million. The largest single import categorywas toys and novelties with a value of $38.3 million; second largest item imported was textile and clothing valued at $30.2 million. The largest export category was household goods with a value of $15.2 million; the second largest category among export goods was transportation equipment and machines valued at $13.1 million. In terms of tonnage, however, lumber had the greatest import tonnage, and potash the greatest export tonnage.

FIGURE IV.3.5 TONNAGE SERVICED BY THE SAN DIEGO PORT



SOURCE: SAN DIEGO BAY, CALIFORNIA. A REVIEW, BENEFICIAL USES, WASTE DISPOSAL PRACTICES, WATER QUALITY; IRVING TERZICH, 1965.

Shipbuilding

The shipbuilding industry provides employment for five times as many workers today as it did less than 20 years ago. The current labor force of almost 4,000 workers is expected to increase to 6,750 by the year 1990. This increase would, however, represent no change in the industry's percentage of the total San Diego County labor force, and is expected to remain constant at one per cent. The economic value of shipbuilding has grown from $6.5 million in 1950 to $91.7 million in 1967.

Some 20 shipbuilding and repair firms scattered throughout the Bay conduct operations ranging from the construction and repair of large vessels to alterations on small fishing boats. Commercial shipbuilding and repair operations have increased as the result of the closing of the U. S. Naval Repair Facility in 1964. The building and repair of naval vessels is now a major industry using the Bay as a resource.

Fishing

San Diego Bay services the world's largest annual tuna catch. It is estimated to represent approximately 45 percent of the total world catch and to have a value of $21.7 million. The number of persons annually employed in fishing in the San Diego area has decreased by almost half since 1950, from 2,050 to 1,100. This

is expected to remain stable at approximately 1,300 for the projected years of 1975, 1980, and 1990. The fishing industry now provides about 0.2 per cent of the County's employment.

Fish canneries in the San Diego Bay area are primarily engaged in the processing of tuna caught by a 100-boat fleet operating out of the Bay. More than 4 million cases are processed annually by the five canneries located in the area. Thawing and fluming of fish is done on the Bay shore.

San Diego Bay serves as a refuge, feeding, and nursery area for fish. As such, it effectively influences the fishery resources of the surrounding ocean. Approximately 100,000 persons, 80 per cent from out of town, fish from commercial fishing boats which operate out of San Diego Bay.

Fish and Animal Reduction

In fish and animal reduction, solid and liquid wastes from fish canneries and solid wastes of animal origin are processed for oil and grease. The remaining solids are dried and converted to chicken feed.

Animal entrails originally washed with Bay water are now flushed with fresh water; however, a cooker and drier fumes washer is operated with water from San Diego Bay.

Kelp

There is an abundant supply of kelp in Pacific Ocean offshore waters. Its chief value is as a source of iodine. The San Diego Bay area is a natural location for the kelp-processing industry.

Chemical Industry

The San Diego Unified Port District operated an oil separation unit at its Tenth Avenue Marine Terminal for processing ballast and bilge water of ships using District facilities. The unit has a capacity of 1.0 mgd, but has been used intermittently and far below its capacity.

Manufacturing

Manufacturing is the largest civilian, non-governmental component of the economy of San Diego County. It is largely dependent on aircraft and ordnance production. In 1967, 32,200 of the County's 61,700 manufacturing employees (or slightly over 50 per cent) were in aircraft and ordinance. The total manufacturing payroll for 1967 was over $496 million.

Trade (Wholesale and Retail)

In 1967, total annual wages in the trade-industrial category were

approximately $339 million, or 24 per cent of the total San Diego County civilian payroll. From 1960 to 1967, the wholesale-retail trade payroll increased 151 per cent, with the greatest increase occurring between 1965 and 1967. Trade represents the second largest civilian payroll category in San Diego County.

Tourism

The third largest industry in San Diego is tourism. Estimated total visitor expenditures have increased approximately 50 per cent between 1960 and 1967, with the sharpest rise occurring during the 1965 to 1967 period. In addition to Bay clean-up, opening of the San Diego Convention Center in 1965 undoubtedly influenced this increase.

In 1967, 446 conventions met in San Diego and contributed approximately $42.5 million to the area's economy. It has been estimated that each delegate remained an average of 4.18 days and spent about $35.50 per day. San Diego County's 1967 hotel-motel occupancy rate of 75 per cent ranks among the highest in the Nation.

Education

As previously mentioned, San Diego's public and private schools employed 33,900 or 8.9 per cent of all civilian employed persons

in 1967. During the last five years, 11,500 persons were added to the education payrolls, an increase of 49.1 per cent.

Federal Civil Service

The number of Federal civilian government employees in 1967 was 83,500. This was 47 per cent higher than the 56,550 employed in 1960. The total wages paid to Federal civilian employees in 1967 was about $225.6 million.

Recreation

San Diego County is fortunate in having an abundant supply of mountains, beaches, and other places of recreational value. In 1965, according to the County Planning Department, a total of 17,157 acres of land was used for recreational purposes:

Study Area	Acres
I	1,868
II	9,427
III	5,862
Total (County)	17,157

Beaches

Existing ocean beaches in the County are a major recreational

attraction for both residents and tourists. Of the 70 miles of ocean shoreline, exclusive of bays and inlets, about 24 miles are suitable for swimming activity, and half of this is accessible to the public. The following future County beach area requirements have been projected based on standards developed by the California Public Outdoor Recreation Plan Committee Report, Part II, 1960:

Year	Acres
1968	225
1975	259
1980	291
2000	366

Current beach area capacity would therefore appear to be adequate, although it may be necessary to develop access roads to those beach areas which are now inaccessible to the general public.

Boating

The number of registered pleasure crafts using San Diego Bay was approximately 4,000 in 1955; 20,000 in 1965; and more than 24,000 in June of 1968. San Diego Bay's permanent mooring facilities can currently accommodate 2,404 boats, and there are an additional 611 dry storage spaces. Plans are under way to almost double the mooring facilities by provisions at Shelter and Harbor Islands.

Approximately 50,000 trailered pleasure craft use the waters of San Diego Bay annually. Total investment in all pleasure craft using the Bay has been estimated at $35 million. The full economic impact of boating would also include fuel, boat maintenance, visitor spending (food, hotels, entertainment, etc.), and rentals for boats and their berths. A private developer in the Imperial Beach area is planning a residential community of 3,500 units, each with its own boat slip, to be constructed over a 10 year period.

Swimming and Beach Use

According to the California Department of Parks and Recreation, Planning Monograph No. 4, the most popular summer outdoor recreational activity in the San Diego Metropolitan District is swimming, with 84,000 participants; driving for pleasure is second, with 54,000 participants; and walking for pleasure is third, with 49,000 participants. For persons of 12 years and older, the age group of 12 to 17 years has the greatest number of outdoor recreation participation days. Where available, beaches would therefore seem to be the most useful summer recreational resource for the population as a whole, and especially for the teenage population. The requirement for swimming facilities is expected to more than double by 1980 when a demand of 184,000 participants is projected for the County.

Recreation Outlook

According to Outdoor Recreation Outlook to 1980 by the California State Department of Parks and Recreation, population in the San Diego area is expected to increase from 1,049,000 to 1,800,100 between 1960 and 1980, or 71.6 per cent. The number of recreation participation days is projected to increase from 107,300,000 to 212,000,000, an increase of 97.5 per cent based on population and participation days data.

The total recreational benefit in 1970 is projected to be over $135 million. Of this, $40 million is related to water oriented sports such as swimming, boating, etc. An unknown percentage of the approximately $80 million relating to walking, driving, sightseeing, picnicking, etc., is attributable to the presence of San Diego Bay. Total recreational economic benefits have been projected as almost $280 million for 1980, a more than three-fold increase in comparison with the estimated $91 million for 1960.

MISSION BAY
(IV-3-3)

The preceding presentation primarily reflected the situation in San Diego County and reviewed that situation in light of the economic base supplied by the Bay estuary. However, another very

important part of the San Diego scene is Mission Bay. This particular bay is an excellent example of recreational possibilities available in an estuarine system.

Mission Bay was formerly no more than a mud flat in a tidal area. However, its development is comparable to the possibilities of any large estuarine situation where a portion of the system can be devoted to special recreational pursuits. The particular value in such a situation is that the use of special areas need not interfere with the major uses of the estuary, although the amount of pollution in the estuary must be limited so as not to preclude use of the recreational portion.

The following summary of the Mission Bay experience points up the multitude of possibilities that are available for recreational and economic development in an estuary given some initial investment of time and money.

Mission Bay Park is the Nation's largest municipally owned aquatic park and provides for public recreation in conjunction with land reclamation, water conservation, and commercial enterprise. It was dredged out of the large tidal mud flat located about two miles north of the northwest section of San Diego Bay, and lies entirely within the City of San Diego.

Development of the 4,600 acre aquatic playground was initiated in 1946 when the voters of the City of San Diego authorized a $2 million bond issue to finance it. Shortly thereafter, the U. S. Army Corps of Engineers established a floodway separating the San Diego River from Mission Bay. Subsequent dredging operation by both the Corps and the City of San Diego opened up the entire Bay and created the many coves and islands which form its land masses.

By the end of 1966, the City had invested a total of $14.5 million in the development of Mission Bay: $9 million from three bond issues, and $5.5 million in capital outlay funds. The State of California contributed 2,900 acres of tidelands, and $3.5 million for the realignment of public utilities and the construction of new bridges. By the time of its anticipated completion it has been estimated that a total of approximately $56 million in public funds, and $50 million in private funds, will have been invested in Mission Bay. In short, many public agencies and private groups have been and will continue to be, instrumental in the development of the $106 million water playground known as Mission Bay.

The Park is a multiple-use project covering 2,500 acres of water and 2,100 acres of land area. Most of the Bay has a depth ranging from 6 to 12 ft at mean lower low water. The Park includes six

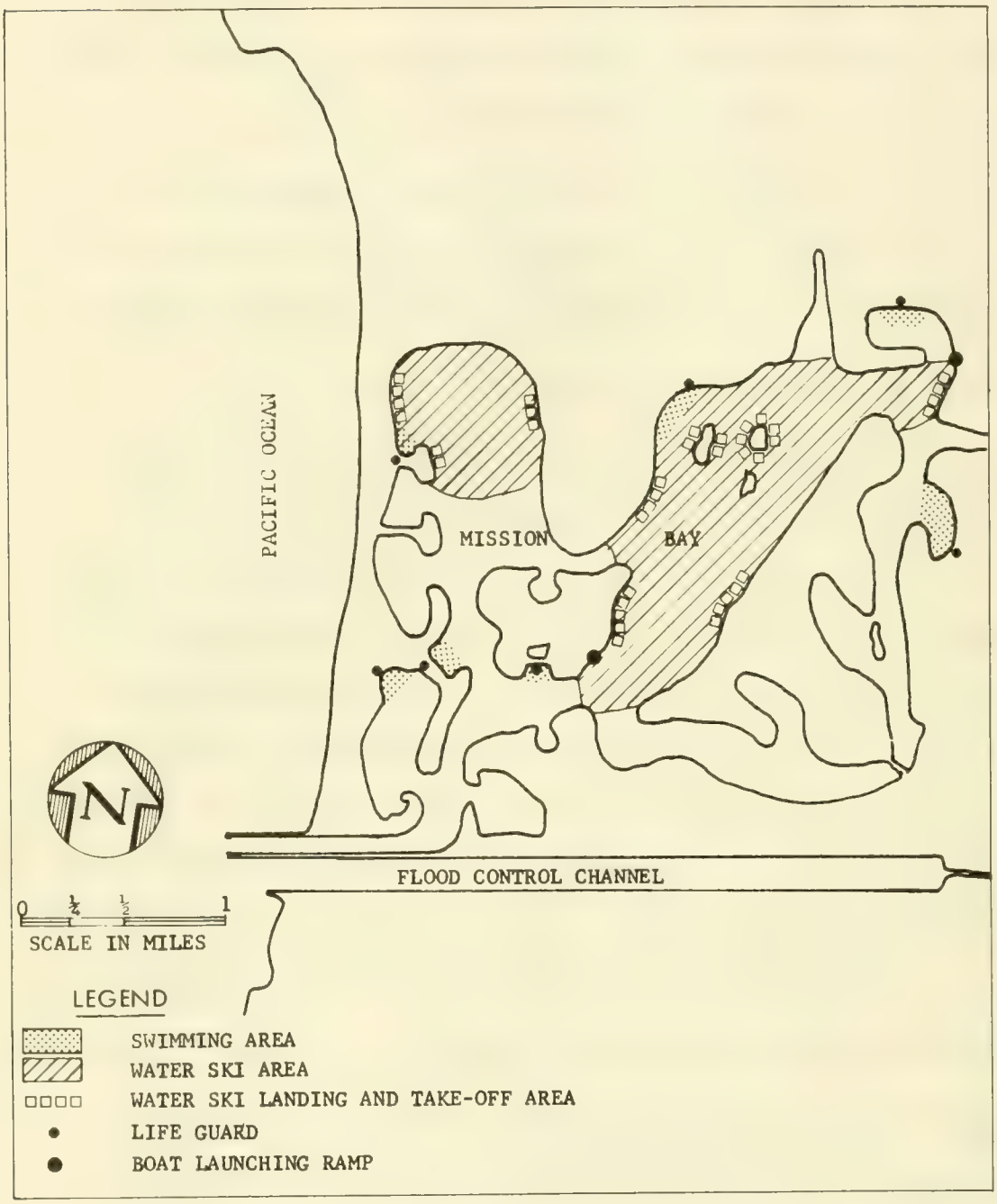
islands, ten peninsulas, two small craft basins, ten coves, the entrance channel from the Pacific Ocean, two large open water areas, and Vacation Isle. Figure IV.3.6 shows the location of the park-complex's various recreational facilities.

There are approximately 27 miles of beaches at Mission Bay with supervised swimming in seven areas. During the 1965-66 fiscal year, the total recorded attendance was 484,702 persons exclusive of the low-attendance winter months.

There is no charge for the use of the concrete launching ramps which the City provides in designated sections of the Bay. An estimated average of 200 boats are launched on weekdays, 600 over weekends. A special area is set aside for sail boating and controlled-speed boating activities. Four large marinas - with slips for 1,200 boats and dry storage accommodations for 250 boats - serve the larger power boats and sailboats using the Bay and the Ocean beyond. Ultimately, it is planned to construct slips for a total of 12,000 boats. Power-boats racing on Mission Bay has attracted wide interest. Fiesta Bay can accommodate all classes of racing inboards including unlimited hydros.

Sport fishing is permitted anywhere in the Bay except for official swimming areas and those designated for water ski landing and take-offs. Anglers from the metropolitan San Diego area make extensive

FIGURE IV.3.6 EXISTING WATER RECREATION AREA MISSION BAY



SOURCE: CITY OF SAN DIEGO - RECREATION DEPARTMENT, AQUATIC DIVISION

use of Mission Bay waters where the following may be caught: bonito, barracuda, spotfin, and yellowfin croakers, rubberlip and shiner surfperch, California halibut, jacksmelt, and topsmelt. It is anticipated that good fishing conditions will continue as long as the waters remain free from pollution.

The University of California maintains a small wildlife preserve near Rose Creek Inlet which is used primarily for bird watching and bird study of waterfowl, gull, and shorebirds. Because it is illegal to discharge firearms within the City of San Diego, there is no waterfowl hunting on the Bay.

The quality of Mission Bay waters depends primarily on the physical characteristics of the Bay. The temperature, clarity, and dissolved oxygen concentration in the entrance channel tends to approximate that of the adjacent ocean. Although dissolved oxygen nitrates and phosphates are low, the presence of phytoplankton and suspension of bottom materials caused by water motion contribute to turbidity. As measured by coliform indicators, the bacterial quality of Mission Bay is excellent.

There is virtually no direct discharge of waste to Mission Bay except for overflow from Sea World's display tanks, and infrequent overflows from the municipal sewerage system and boats. The use of marine heads in the Bay is discouraged. There are drying beds for

liquid digested sludge on Fiesta Island. Their use conforms to the requirements of the San Diego Regional Water Quality Control Board, and their presence has created no known problems.

Sea World Aquatic Park is a unique, privately owned marine exhibit located in Mission Bay Park. After filtering to improve clarity, Bay waters are used in the exhibit and performance tanks.

There is a heavy demand for the 1,000 rooms offered by resort hotels in or adjacent to Mission Bay Park. These are largely classified as luxury accommodations. In addition, there are trailer park accommodations of 653 spaces. Facilities for tourist accommodations are expected to increase, and one hotel is planning to provide an additional 127 rooms for visitors as well as additional convention rooms.

Summary of Case Study Reviews

Narragansett Bay is an ideal example of an estuary that has developed in an unbalanced fashion. That is, the economic value of the estuary at the present time is largely associated with the industrial, military, and transportation uses of its waters. Other uses are, of course, made of the estuary but their economic significance is dwarfed by the tremendous magnitude of the military

and commercial uses. However, it must be remembered that this economic measure is merely an indicator of the value of the waters and is not in any way related to the right or necessity of polluting such waters in the process of achieving this value. In fact, the only time that such an economic measure would be used would be for comparing one total use of the estuary to another total use. Of course, it is seldom that questions are so broad as to cover either/or propositions for the entire activity. Rather, the questions usually revolve around such things as the benefits to be derived from reducing pollution caused by users of the estuary compared with the costs of achieving the reduction in pollution.

Franklin County, Florida, is dependent upon pollution-free waters in Apalachicola Bay for its economic existence. The unpolluted waters of the Bay provide the seafood caught by local commercial fishermen and processed at shore-based installations. Additional income for the area results from tourism engendered by the Bay's waters.

Both tourism and commercial fishing are prime potential sources of income to any estuarine system. In the case of Apalachicola Bay, these happen to be the major sources of income because of the

nature of the estuary and its location which prevent its development as a commercial shipping facility.

The San Diego economy, although heavily dependent upon the military and shipping activities in the Bay, has diversified to the extent that it is no longer completely dependent upon such uses of the Bay. At the same time there has been a growing demand for recreational uses of the Bay. Evidence of the local resident's interest in the Bay for recreation, tourism, and commercial uses can be found in their willingness to invest substantial sums of money in facilities to prevent pollution of the Bay by municipal wastes.

Mission Bay, a separate estuary in the San Diego area, is an example of the recreational potential to be found in an estuarine system. However, this special study points up the fact that the best use of an estuary may not come about naturally. Rather, it shows that a planned development program with adequate investments are necessary to achieve optimal use of an estuary.

In summary, then, it can be seen that the major uses of estuaries vary from one estuary to another, depending upon historical development and suitability for specific uses. However, the primary points indicated by these various estuary reviews are:

(1) estuaries are adaptable to several different uses; (2) current use of any given estuary is not the sole indicator of the estuary's value; and (3) with adequate effort the recreational and social aspects of an estuary can become vital parts of that estuarine system.

SECTION 4. MEASURES OF VALUE AND IMPORTANCE OF THE ESTUARINE ZONE

The discussions of values of individual uses and the case studies of specific estuarine systems present a confusing picture of the relationship of estuarine uses to economic indicators.

Estimates of the direct gross economic benefit of the estuarine zone to the residents of the coastal counties can be made. The estimates of economic activity generated by the presence of Narragansett Bay in Rhode Island give a conservative annual economic benefit of $920 per capita, $420 of this in personal income. Average personal income for all of the coastal counties is, according to Bureau of the Census figures, $500 per capita greater than the average for the remainder of the country. The total economic activity generated by this additional personal income then amounts to about $1,100 per person, using the Narragansett Bay multiplier values.

The total direct economic benefit of the estuarine zone to the residents of the coastal counties is then about 60 billion dollars in terms of additional economic activity stimulated by the presence of estuarine systems. This is not a measure of the total economic activity of the estuarine zone, but only of the "value added" to the total economic activity of the coastal

counties by the presence of the estuarine zone.

Such gross means can give only an order-of-magnitude estimate of even the direct economic value of the estuarine zone and cannot possibly reflect either indirect benefits or the social importance of the estuarine zone, much less its ecological value.

Valid criteria for evaluating the importance of the estuarine environment or the value of individual estuarine uses, to a community must, however, go beyond the reach of economic approximation and recognize the fundamental relationship between man and his environment. Wherever there are people the environment will be exploited to satisfy the needs and desires of man and his civilization.

Increasing environmental pressures from demographic and commercial development are paralleled in the same community by the increasing desire for greater recreational use. That these can be compatible is clearly shown by the San Diego Bay example. Such community reactions as in San Diego and in San Francisco demonstrate that, while people need commercial development and use, they want a safe and enjoyable environment at the same time. Effective management, therefore, should direct its efforts not toward excluding some uses, but toward accomodating all uses without environmental damage.

With such an objective, economic criteria of use importance are of little value. Guidelines for estuarine management should recognize man's relationship to his environment and express his determination that it shall be preserved.

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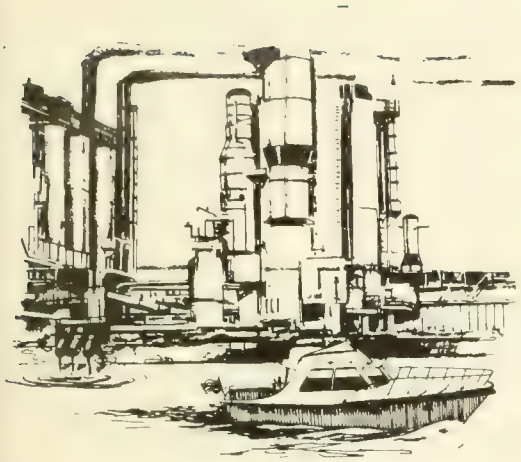
IV-3-2 Colberg, M. R., "The Social and Economic Values of Apalachicola Bay, Florida," (Report prepared for National Estuarine Pollution Study under FWPCA Contract No. 14-12-117) by Tallahassee, Florida, Florida State University, mimeographed copy, 58 pp (1968). (In press.)

IV-3-3 Ralph Stone and Company, "Estuarine-Oriented Community Planning for San Diego Bay," (Report prepared for National Estuarine Pollution Study under FWPCA Contract No. 14-12-189) by Ralph Stone and Company, Los Angeles, California, mimeographed copy, 178 pp (1969). (In press.)

Chapter 4

SOCIAL AND ECONOMIC TRENDS



This part of the report emphasizes the complex interaction among the biophysical and socioeconomic environments within the estuarine zone. The existing socioeconomic environment is the subject of the preceding chapter; this chapter deals with trends associated with the social and economic environment.

The availability of certain resources in or near estuaries has strongly influenced patterns of population growth and economic activity. Once initiated, these changing economic and demographic patterns alter the nature of the estuaries themselves. For example, the presence of plentiful timber resources was a factor in the development of many coastal towns and cities. Long after the depletion of the timber resource, the deep deposits of sediments carried down from the scarred land to the estuary bottom alter the biophysical system. Similarly, new sets of economic activity such as transportation, manufacturing, and commerce replace the initial extractive lumbering activity and in turn affect the biophysical environment.

Other trends, stemming from pressures wholly or partially external to the estuarine environment, may also have profound influence. For instance, the changing economic demands of a dynamic society affect the location and composition of economic activity and populations in the estuarine zone. Thus, changes in labor markets, location of raw materials, and prices determined to a large degree the shift of textile manufacturing from the New England coast to the South.

Barring catastrophes or other unforeseen developments, certain trends are expected to continue in the country at large. Rapid population growth and continued development of urban-suburban areas are notable among the demographic projections, while the economy is expected to show continued diversification, technological change, and expansion. To assess the impact of these trends on the estuarine zone, the reasons for the distribution of future population and economic growth must be understood; and an understanding of past and present trends indicates in a general way what may be expected.

The discussions in this chapter provide a basis for projecting the changes that may be brought about by man's continuing activities in the estuarine zone.

This chapter was summarized from the report "Social and Economic Trends associated with the Nation's Estuarine Region," prepared by Harold F. Wise and Associates under contract with FWPCA as part of the National Estuarine Pollution Study. The report is now being prepared for publication.

SECTION 1. NATIONAL POPULATION AND ECONOMIC TRENDS

NATIONAL POPULATION GROWTH

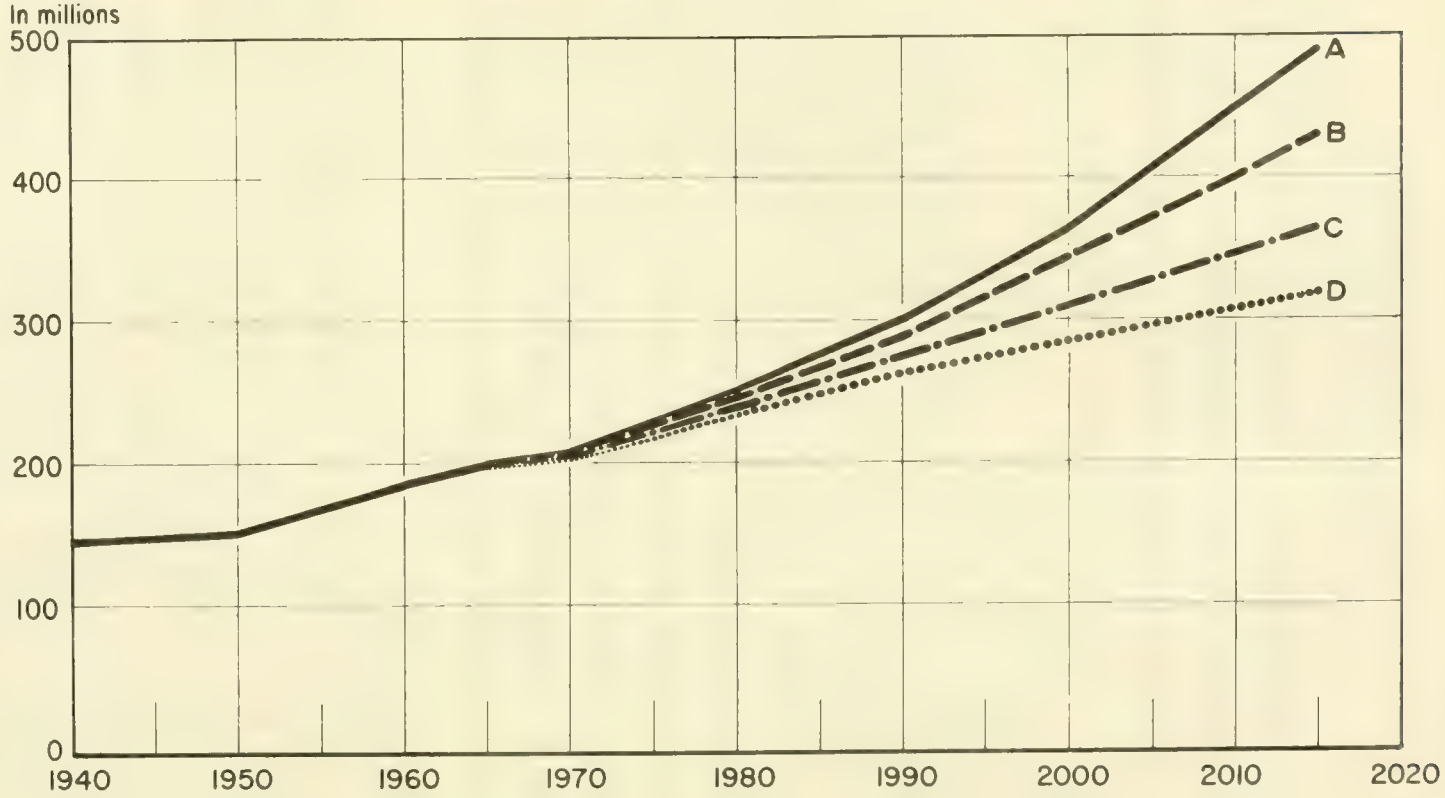
America has experienced a continually high rate of population growth. Today there are six times as many Americans as there were one hundred years ago, and more than twice as many as there were 50 years ago. This growth is expected to continue in the future, though likely at a slower rate.

Figure IV.4.1 provides clear evidence of the "population explosion" which took place in the United States in the years following World War II. In the decade 1950-1960, the total United States population increased by nearly 28 million persons, a growth rate of 15.6 percent for the decade, or an annual population growth rate of nearly 1.6 percent. That growth is expected to continue at a rate of approximately 1.3 percent annually with the total population of the United States increasing from a little over 205 million persons in 1970 to about 400 million in 2020.

Figure IV.4.2 shows recent population increases and decreases throughout the Nation. Population decreases have occurred almost uniformly in the period 1940 to 1960 in the predominantly agricultural counties of the Mid-West, the South, the Southwest, and Appalachia. In contrast, those counties in which metropolitan development has occurred generally show steady increase during these years. Perhaps the most striking growth record in this period appears in what may generally

Figure IV.4.1

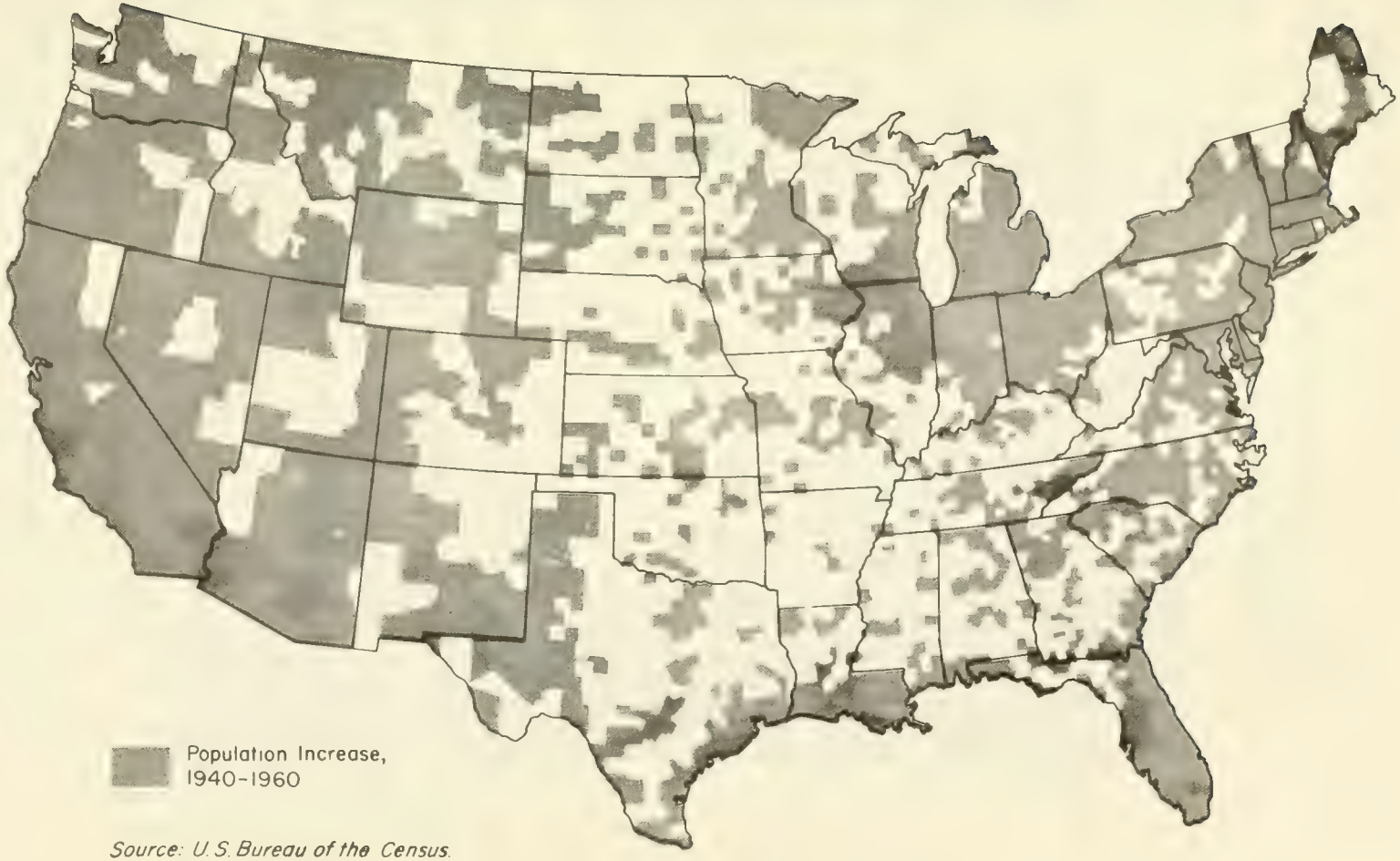
ESTIMATES AND PROJECTIONS OF THE POPULATION OF THE UNITED STATES, 1940-2015



Source: U.S. Bureau of the Census.

Figure IV.4.2

POPULATION TRENDS IN U.S. COUNTIES, 1940-1960



Source: U.S. Bureau of the Census.

be designated as the coastal zone, where only a handful of some 274 coastal counties experienced any population decline during either of the ten-year periods between 1940 and 1960.

URBAN-RURAL SHIFTS

The growth of population in urban areas and relative decline in rural areas has been a steady trend in America since the first Census was taken. As Figure IV.4.3 shows, the 1920 Census marked a symbolic turning point, with urban citizens outnumbering rural ones for the first time. Metropolitanism is fast becoming central to consideration of all aspects of American life. In 1965, 67 percent of the country's population lived in the 212 SMSA's identified by the Bureau of the Budget.

AGE COMPOSITION

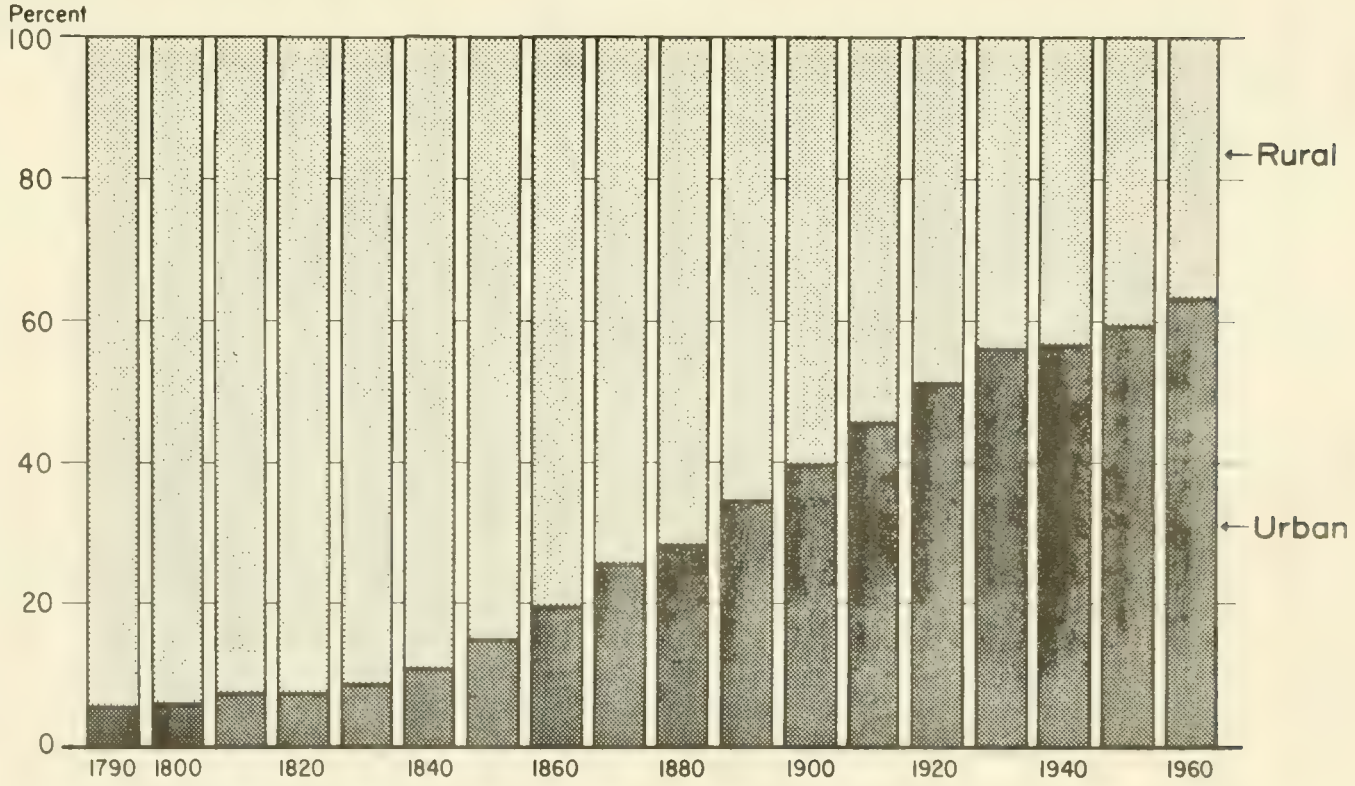
The age composition of the population will also change in ensuing years. Of particular significance is the expected rise in the main working age population (ages 25-64) from 86.4 million in 1966 to about 90.1 million in 1970 and 123.9 million in 1990. From 1975 on, the younger portion of this age group is expected to increase rapidly, while the number of elderly citizens shows only a slight increase.

NATIONAL ECONOMIC GROWTH

The amount of personal income generated in the economy indicates the general capacity to purchase goods, services, and amenities.

Figure IV.4.3

URBAN AND RURAL COMPONENTS OF TOTAL UNITED STATES POPULATION, 1790-1960



Source: U.S. Bureau of the Census.

Figure IV.4.4 shows a steadily rising trend and projection of United States personal income. Total personal income is expected to rise at a 5.1 percent annual rate of growth from 1970 to 2020. In terms of constant 1958 dollars, this represents an increase from about $615 billion to nearly $5 trillion in 2020. Similarly, per-worker earnings will increase substantially, rising from $6,000 in 1920 to $23,000 by 2020 as Figure IV.4.5 shows.

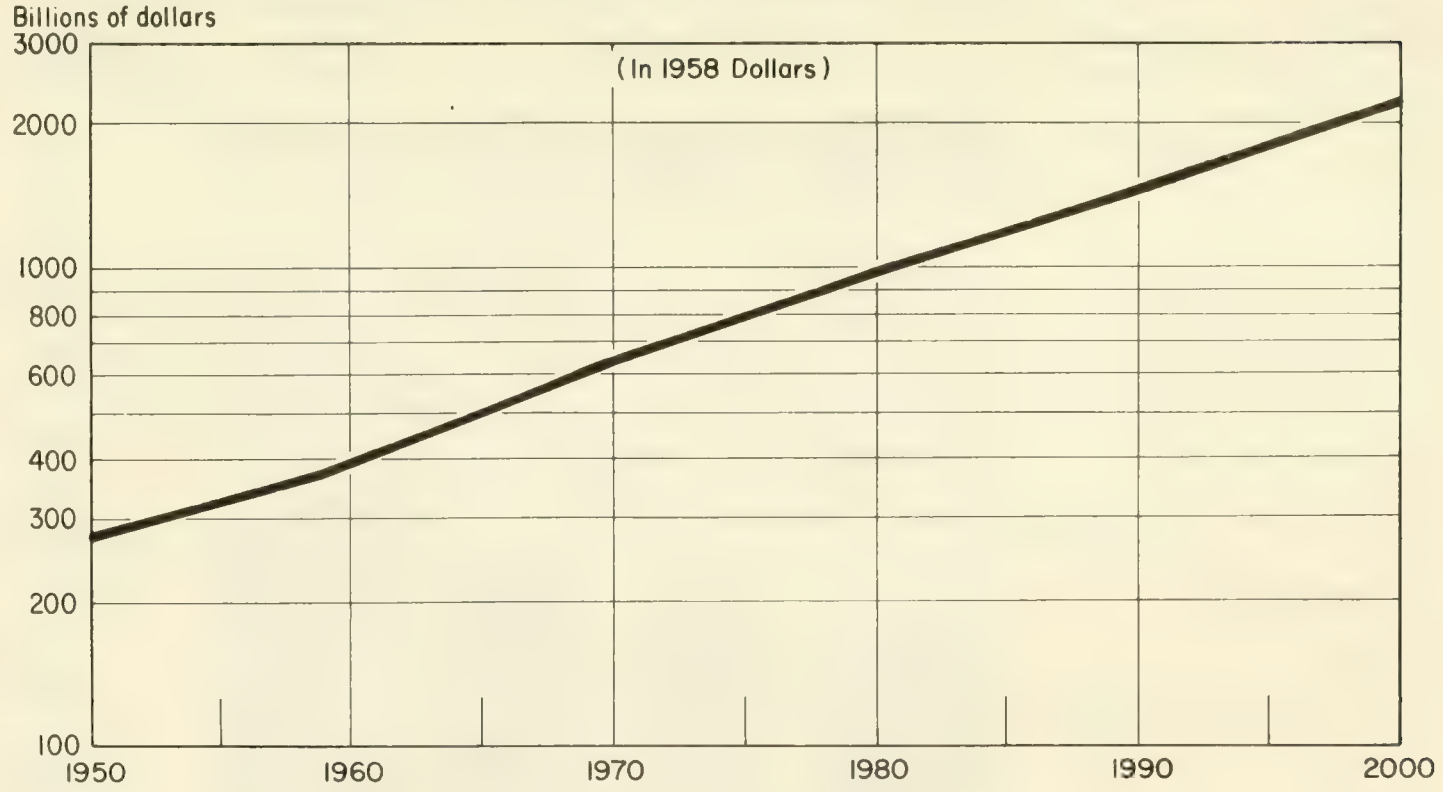
Within the economy, considerable variation in the rates of growth of various sectors is expected. "Goods-producing" industries such as agriculture, mining, and manufacturing will decrease in relative importance, while those which are "service-producing" (e.g., contract construction, trade and finance, and government) will increase. This changing pattern of employment is exhibited in Figure IV.4.6. This figure gives a detailed account of percentages of national employment by broad industrial category.

The fact that employment in agriculture, forestry, and fisheries is expected to show a steady decline from 12.5 percent of total national employment in 1950 to 1.2 percent in 2020 is worthy of speical attention, for combining all three of these categories masks the changes that are actually taking place. A Bureau of Labor Statistics study which treats each of the three categories separately for the years 1960-1975 anticipates:

(1) 1,978,000 fewer agricultural workers in 1975 than in 1960 (a percentage drop from 8.6 percent to 4.2 percent);

Figure IV.4.4

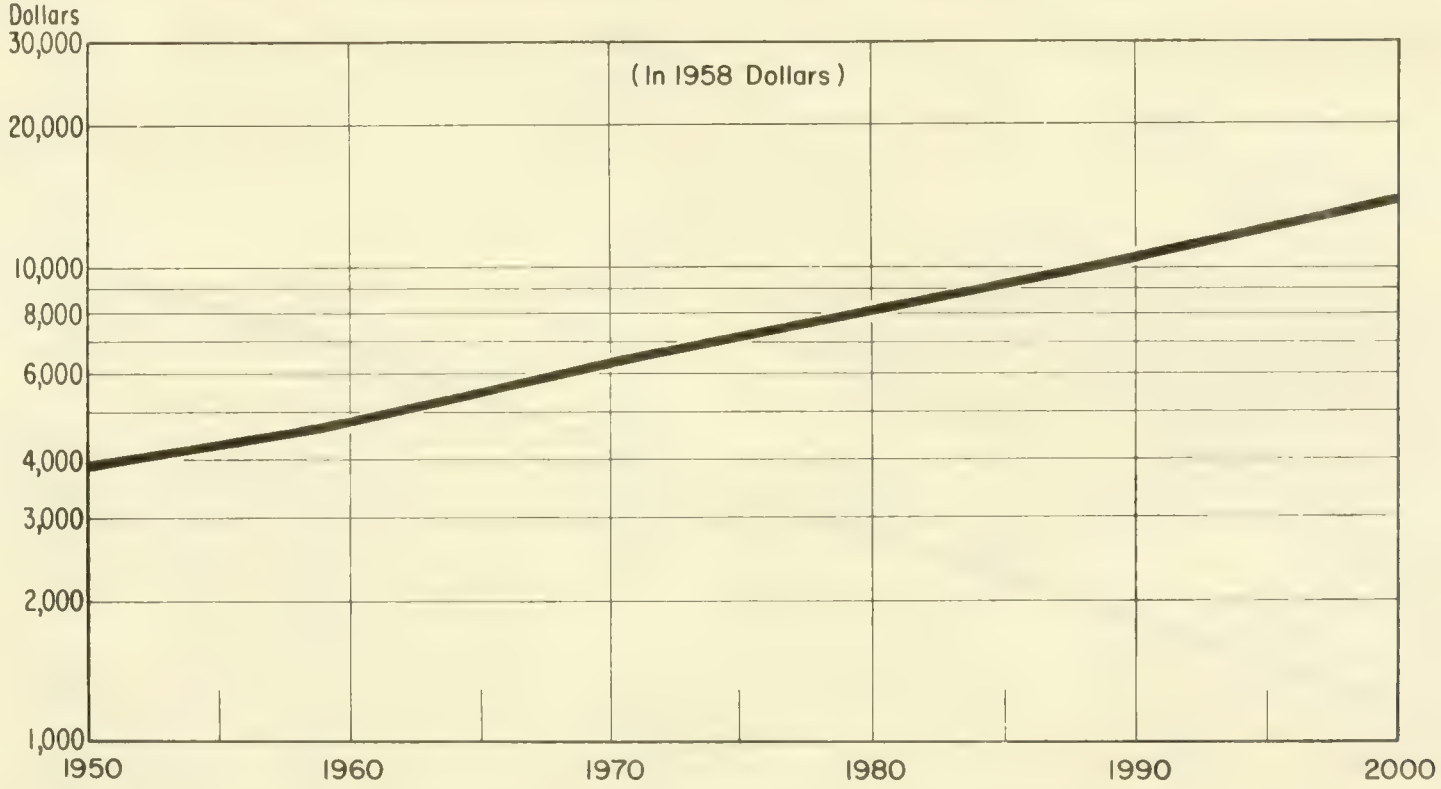
ESTIMATED AND PROJECTED TOTAL PERSONAL INCOME IN THE UNITED STATES, 1950-2000



Source: U.S. Department of Commerce, Office of Business Economics, Regional Economics Division.

Figure IV.4.5

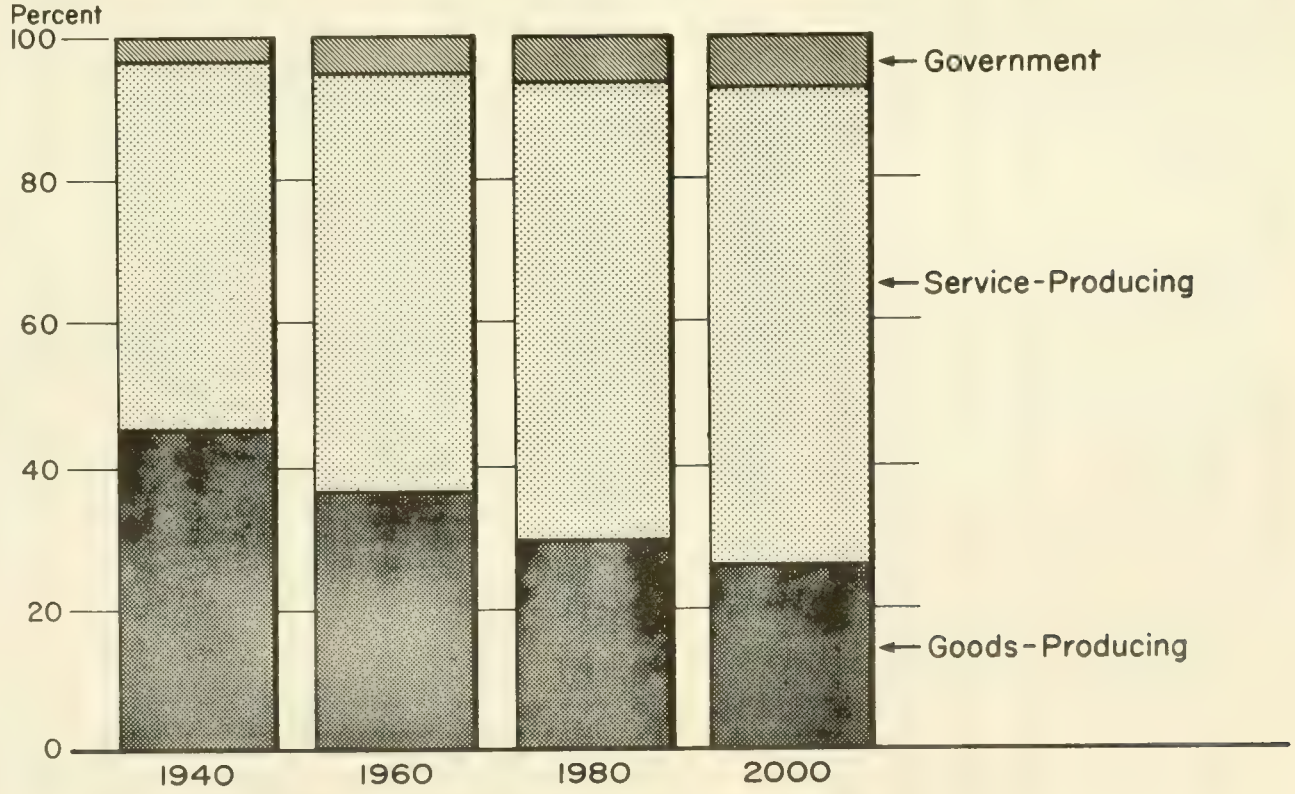
ESTIMATED AND PROJECTED PER-WORKER EARNINGS IN THE UNITED STATES, 1950-2000



Source: U.S. Department of Commerce, Office of Business Economics, Regional Economics Division.

Figure IV.4.6

PERCENT OF TOTAL CIVILIAN EMPLOYMENT IN THE UNITED STATES
Represented by "Goods-Producing", "Service-Producing", and "Government" Sectors,
1940-2000



(2) an increase in forestry employment from 48,000 to 70,000;

(3) growth in fisheries employment from 45,000 to 60,000.

Both forestry and fisheries maintain constant shares of national employment of .7 per cent and .6 percent respectively.

Employment in the "service-producing" sector should exhibit the greatest proportional increase in the foreseeable future. The services group will surpass both manufacturing and wholesale-retail trade in percent of national employment by 1980.

IMPLICATIONS OF THE NATIONAL PICTURE

If normal circumstances prevail, the Nation's population and general high standard of living will continue to increase in the coming decades. A moderate estimate projects a doubling of the national population by the turn of the century, with a significant proportion of that growth occurring in urban areas.

The population will be made up of a large proportion of youth and young persons of working ages, with only a moderate increase in the elderly through the end of the century. Personal income will rise dramatically. Estimates of leisure time vary considerably, but all authorities agree that the workweek will shorten, from a conservative estimate of 35 hours a week to as little as 20 hours per week. The National Planning Association has projected that in 1990, ten percent, and in 2000, twenty percent of the men between the ages of 25 and 54

will be granted a one-year leave every seven years. Urban and particularly suburban growth will expand greatly both to accommodate the growing population and to provide amenities that it increasingly demands: single-family dwellings, recreational areas, transportation facilities, industrial developments, and so on. These demands will place rapidly increasing burdens on the Nation's resources and its environment. These burdens, in turn, will tax the ability of decision-makers and the Nation's population to cope with the complexity and insistence of the problems generated by a post-industrial, urbanized society.

SECTION 2. TRENDS IN THE ESTUARINE ZONE POPULATION AND ECONOMY

FUTURE POPULATION GROWTH IN THE ESTUARINE ZONE

The estuarine zone economic region includes the coastal counties plus a few non-coastal counties included as part of estuarine zone SMSA's*. The overall recent population growth rate in the estuarine zone economic region has exceeded that of the Nation as a whole. From 1930 through 1960, the population of the coastal counties and SMSA's increased 78 percent, compared to a national growth rate of 46 percent. Future population growth is projected to continue above the national average, but at a somewhat lower rate. Estuarine zone population is expected to more than double between 1960 and 2020 from

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*SMSA's are Standard Metropolitan Statistical Areas.

60 million to 139 million persons. Approximately 35 percent of the Nation's total population will then be located on the land area encompassed by the national estuarine economic region.

This report focuses on the characteristics of the major urban regions presented in Figure IV.4.7. Three of the four major urban regions anticipated by the year 2000 front on the coastal zone: the Atlantic Seaboard Region, the Florida Peninsula Urban Region, and the California "Megalopolis." The Lower Great Lakes Urban Region does not border the marine coastal zone but is contiguous to the Great Lakes.

Major characteristics of the three coastal-related major urban regions are set out below:

(1) The Atlantic Seaboard Region extended from Augusta, Me. to Prince William County, Va., in 1960, covering 50,553 square miles with a total population of 37.5 million. By the year 2000 it will increase in size to 64,800 square miles and will contain 78 million persons. It will then extend south to Hampton Roads, Va. and increase in density from 741 persons per square mile to 1,050.

(2) The Florida Peninsula Urban Region included 11,300 square miles in 1960 and contained 3.3 million persons. By the year 2000 the region is expected to cover 20,000 square miles and contain nearly 14 million people.

(3) The California "Megalopolis" will close the gap between the two major urban areas existing in Calif. in

Figure IV.4.7

Urban Regions in the Estuarine Zones in the Year 2000

1960, the Southern California Urban Region which extends from the Mexican border in the south to San Maria on the north and has a population of 8.9 million, and the Bay Area-Central California Region, extending from southern Monterey County to Sonoma County in the north and inland to Modesto with a population of 4.9 million. In 2000 it will be an agglomeration of urban and metropolitan zones 600 miles in length with a population of 44.5 million people.

Graphic presentation of the growth of these major regions is presented in Figures IV.4.8, IV.4.9, and IV.4.10.

The three other urban regions which are expected to develop in the estuarine regions by the year 2000 are described below:

(1) The Central Gulf Coast is expected to have a population of 2.1 million by 1980. By 2000 the region is projected to reach from Baton Rouge, La, to Pensacola, Fla. and contain 4.7 million people.

(2) The Texas-Louisiana Gulf Coast roughly parallels the coast and has experienced substantial growth in recent decades. The region extends from Houston to Lake Charles, La., and is expected to grow in population from 1.8 million in 1960 to 5 million in 2000.

(3) The Puget Sound which will expand its area to include additional population to the Canadian border, will

Figure IV.4.8
Atlantic Seaboard Urban Region

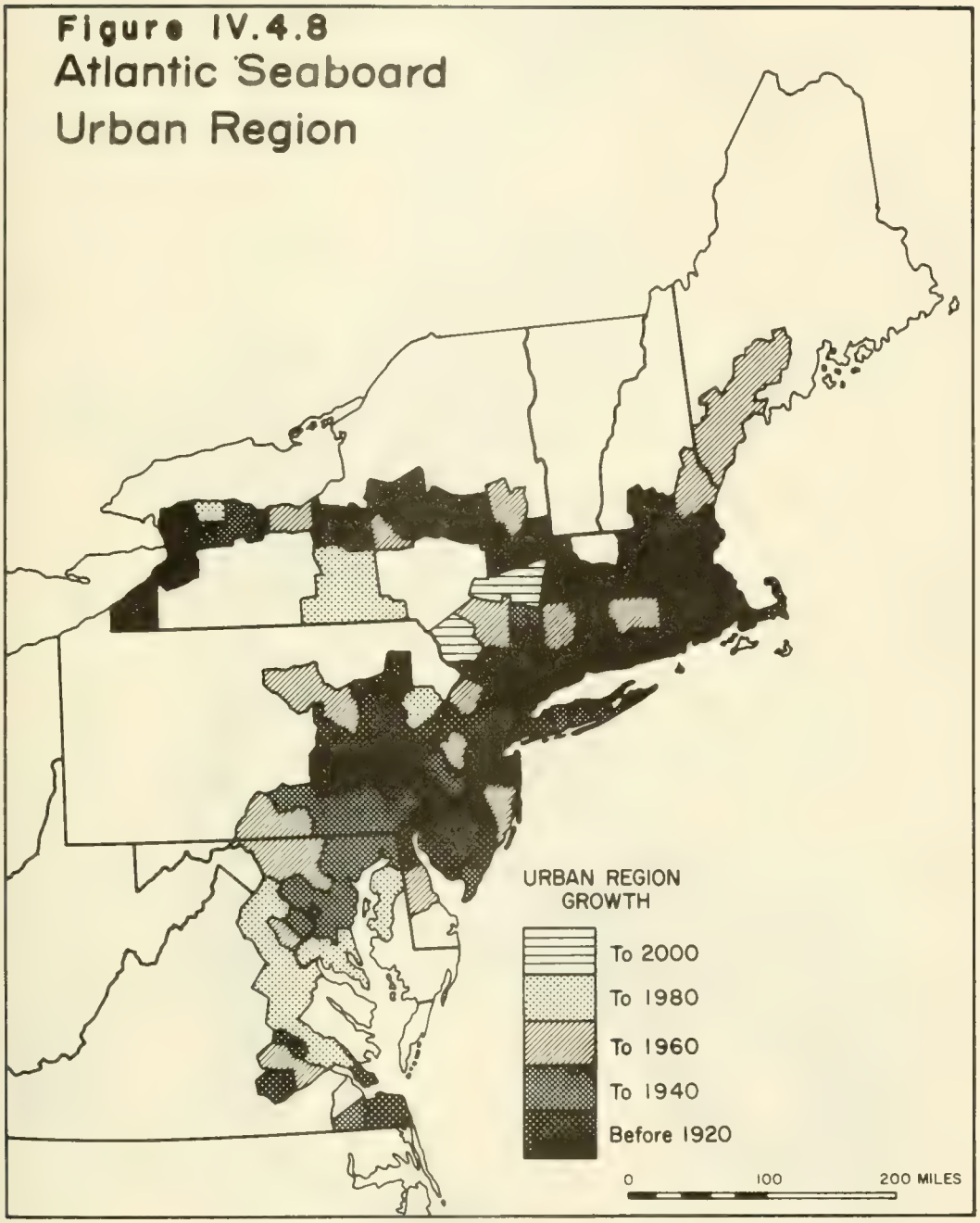
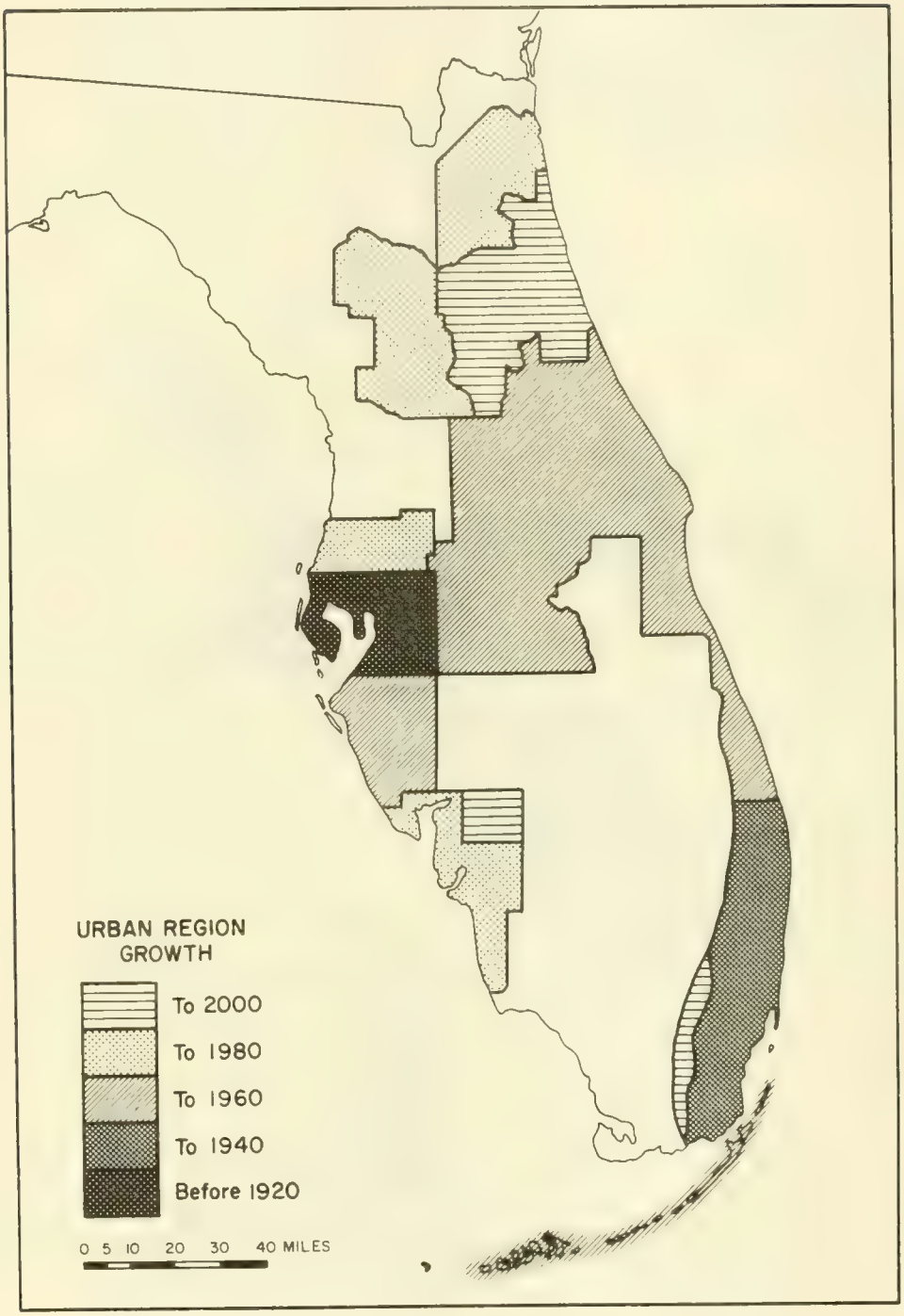


Figure IV.4.9

Florida Peninsula Urban Region



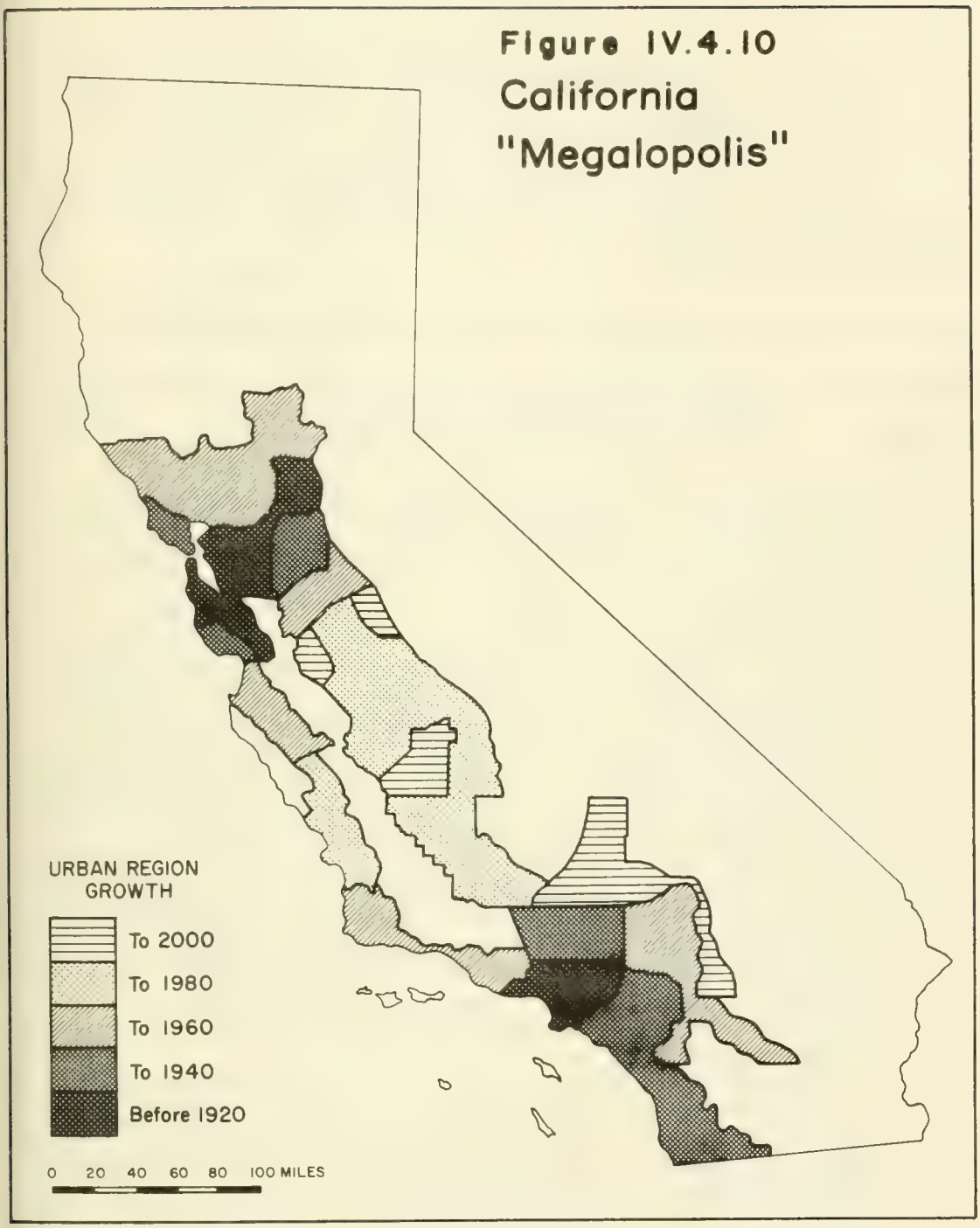


Figure IV.4.10
California
"Megalopolis"
URBAN REGION
GROWTH
To 2000
To 1980
To 1960
To 1940
Before 1920
0 20 40 60 80 100 MILES

increase in population from 2.5 million persons in 1980 to 3.6 million in 2000.

Urban growth has both a direct physical impact on estuarine resources in the usurpation of land for development purposes, and an indirect impact in increased runoff, changed water composition, and increased demand for water supplies.

Other implications are also important. By and large, urban populations are those which most strongly feel the effects -- good and bad -- of increased per capita income, leisure time, and mobility. There are, speaking very generally, three segments of the urban population affected by these forces, and they react differently in terms of the estuarine environment. The groups and the implications are:

(1) High Income: Urban residents with high income place pressure on the estuarine environment some distance from their place of residence. They are able to afford either second homes or extended stays at vacation resorts. Much of the total national demand expressed by that segment of the population in the upper middle and high income brackets falls on the non-urban portions of the coastal-estuarine zone.

(2) Middle Income: Those persons with middle range incomes either opt for new housing in the suburban ring surrounding the central city or choose to remain within the central city. In either case, their mobility is increased by their

ability to afford leisure time activities removed from their place of residence. The pressure is likely to fall on public areas in the coastal-estuarine zone.

(3) Low Income: Residents of the central city with low incomes are not able to leave the confines of the central city. Their enjoyment of the coastal-estuarine zone resources is tied tightly to the quality of the coastal-estuarine interface within the central city itself.

FUTURE DISTRIBUTION OF POPULATION GROWTH IN THE BIOPHYSICAL REGIONS

Table IV.4.1 gives a comparative breakdown of population growth rates in the estuarine economic areas defined by the Office of Business Economics (OBE) compared to national growth. Individual areas showing a population growth rate lower than the Nation's during the 1930-1960 period are clustered in the North and Middle Atlantic biophysical regions and include the Maine coast, Massachusetts-Rhode Island coast, New York and Northeast New Jersey coast and the Philadelphia-New Jersey-Delaware areas. These areas, with the possible exception of the Maine coast, are mature areas which experienced an early growth in population and reached a large population density relatively quickly. They are now growing comparatively slowly. Highest relative growth between 1930 and 1960 (more than 100 percent above the national average) took place in four areas: Florida, the Mississippi-Alabama-West Florida coast, Texas, and California. These areas are expected to experience extensive

TABLE IV.4.1

Population Growth Rates in OBE Estuarine Economic Areas
Compared to National Growth
1930 - 1960

National Population Growth Rate:	46 percent
Total Estuary Economic Region Growth Rate:	78 percent
Percent Difference	+32 percent

Individual Estuary Economic Areas	Percent Growth Rate	Percent Difference to National Growth
1. Maine Coast	26	- 20
2. Massachusetts-Rhode Island Coast	22	- 24
3. Connecticut Coast	48	+ 2
4. New York-Northeast New Jersey	38	- 8
5. Philadelphia- N.J.-Delaware	44	- 2
6. Maryland-Virginia Coast	103	+ 57
7. North Carolina Coast	45	- 1
8. South Carolina Coast	79	+ 33
9. Georgia-Eastern Fla. Coast	312	+266
10. Southern Florida Gulf Coast	261	+215
11. Central Florida Gulf Coast	75	+ 29
12. Miss.-Ala.-W. Fla. Coast	174	+128
13. Louisiana Coast	79	+ 33
14. Texas North Gulf Coast	178	+132
15. Texas South Gulf Coast	153	+107
16. Southern Calif. Coast	206	+160
17. Central Calif. Coast	135	+ 89
18. Northern Calif. Coast	156	+110
19. Oregon Coast	93	+ 47
20. Washington Coast	87	+ 41

short- and long-term growth in the future. Significantly, these areas also reflect a change in life style toward a suburban, leisure-centered existence with its attendant demands for land- and water-related activities.

Actual trends and projections of numbers of persons by OBE estuarine economic area are given in Table IV.4.2 Table IV.4.3 demonstrates population pressure on the available coastline and associated estuaries. That pressure can be summarized as follows:

(1) The New York-Northeast New Jersey Coast Area, OBE area 4 with a population density of nearly 4,000 persons per square mile in 1970 (more than twice as high as the next most densely populated area projected for 2000), will continue to be the most populous area in the United States and exert the most concentrated pressure on remaining coastal open space and water quality from municipal and other wastes;

(2) The southern North Atlantic and Middle Atlantic Biophysical region, OBE areas 2 through 6, will continue to experience the greatest concentration of population and economic activity;

(3) The distribution of major population densities will change from a heavy preponderance located in the North Atlantic and Middle Atlantic region, to a more even distribution including Florida, Texas, and California in

TABLE IV.4.2

Population Density in the
Estuarine Economic Region and Individual Areas
1950-2000

Estuarine Economic Region Population Total	1950 219.1*	1960 280.2	1970 330.7	1980 384.9	1990 449.4	2000 516.9
Estuarine Economic Area Population Total						
1	57.7	61.2	65.1	70.6	77.6	84.3
2	827.7	911.1	987.1	1088.8	1214.5	1341.4
3	463.0	568.7	642.9	720.7	817.5	907.7
4	3054.7	3506.4	3904.8	4295.4	4732.8	5173.6
5	533.8	645.6	720.8	808.3	918.2	1032.1
6	242.7	311.4	369.6	435.3	519.4	606.1
7	43.0	49.3	50.9	52.6	56.1	60.0
8	54.6	67.9	73.3	78.5	86.8	96.5
9	92.5	170.3	238.7	303.3	371.3	448.0
10	69.3	133.9	173.1	210.3	244.2	291.1
11	16.7	21.5	22.8	25.5	29.1	33.7
12	71.9	104.5	124.7	144.9	174.0	204.7
13	93.3	121.6	143.7	156.4	171.8	189.3
14	137.4	194.6	225.9	277.4	338.2	412.1
15	54.7	69.8	78.7	87.2	98.1	108.7
16	309.7	486.7	640.7	804.1	1003.7	1206.1
17	207.0	279.3	357.4	441.5	541.1	643.2
18	17.0	26.7	32.9	41.0	50.1	59.6
19	56.2	65.7	71.5	82.5	95.2	107.5
20	72.4	89.0	104.9	122.9	144.1	166.9

Source: Computed from Office of Business Economics population projections and Department of Commerce County Land Area measurements.

*Densities are expressed in persons per square mile

TABLE IV.4.3
Estimates and Projections of Population in the
Estuarine Economic Region and Individual Areas
(Thousands)

Estuarine Economic Region Total Population --		1950 45,302.1	1960* 57,946.2	1970 68,396.9	1980 76,606.7	1990 92,940.0	2000 106,900.3
Estuarine Economic Area Population Total	1	471.7	499.7	531.5	576.7	633.6	688.2
	2	4,355.4	4,794.3	5,194.3	5,729.2	6,390.6	7,958.2
	3	761.2	934.9	1,057.0	1,184.8	1,343.9	1,492.2
	4	13,593.6	15,603.5	17,376.5	19,114.4	21,061.0	23,022.3
	5	4,399.3	5,320.8	5,939.9	6,661.5	7,567.1	8,505.8
	6	4,473.0	5,739.5	6,812.8	8,023.3	9,573.3	11,172.1
	7	447.1	511.7	529.0	546.1	582.7	623.0
	8	374.8	466.2	503.2	539.0	595.7	662.2
	9	1,432.5	2,637.8	3,698.7	4,699.3	5,752.5	6,941.1
	10	547.7	1,058.7	1,369.0	1,663.1	1,931.0	2,302.7
	11	98.0	126.5	134.2	150.2	171.0	198.1
	12	563.0	818.5	977.0	1,135.3	1,363.3	1,603.2
	13	1,177.8	1,535.3	1,814.7	1,974.4	2,168.6	2,930.0
	14	1,324.7	1,900.8	1,206.7	2,710.4	3.304.1	4,026.1
	15	441.5	563.8	635.6	704.1	792.3	878.2
	16	5,233.5	8,224.9	10,826.2	13,586.9	16,906.1	20,381.0
	17	2,944.2	3,972.6	5,084.6	6,280.3	7,696.9	9,150.2
	18	78.0	122.7	151.0	188.1	230.1	273.8
	19	1,091.4	1,276.8	1,389.3	1,602.7	1,849.6	2,087.7
	20	1,493.7	1,837.3	2,165.5	2,536.8	2,972.6	3,444.1

* For purposes of uniformity, 1960 data is taken from April 1 enumeration.

Source: Office of Business Economics, Regional Economics Division

the South Atlantic, Gulf, and Pacific regions. Examples of this shift in population concentration are found in the Central Calif. Coast, which is expected to grow from a population density of a little more than 350 persons per square mile in 1970 to nearly 600 in 2000, and in the Tex. North Gulf Coast which will experience a population density growth from 225 persons per square mile in 1970 to over 400 per square mile in that same thirty year period;

(4) Although some areas in the United States will remain relatively lightly populated, the pressures of increased population will be felt in even the most remote coastal areas, if not by local population growth, then by increasing demands of more urbanized populations for the amenities of the coastal zone; often expressed in terms of seasonal influxes;

(5) The effects of increased population density will vary according to a number of considerations such as the employment structure, distribution of the population within the area, the biophysical environment, institutional constraints, and so on;

(6) Finally, many of the conflicts generated by competing demands on the estuarine resource, which are most visible in today's metropolitan areas, will intensify in those areas in the future and extend to estuarine areas which

are now relatively unmodified and free of intense competitive demands.

FUTURE ECONOMIC ACTIVITY IN THE ESTUARINE ZONE

The estuarine economic region in recent decades exhibits a rate of economic growth slightly greater than the national average. Personal income in constant dollars expanded 177 percent from 1929 to 1962, while national personal income rose 170 percent. Nearly all parts of the region are expected to either maintain positions of relative wealth in the future or to increase their relative wealth.

Manufacturing is the principal export activity of the region, and the significance of the region as a focus for industry is shown by the level of concentration of employment. In 1960, about one-half of the manufacturing industries had a level of concentration greater than the national level. Significant degrees of overall specialization in the region are indicated in transportation equipment excluding motor vehicles, petroleum refining, apparel, and in both printing and publishing and chemicals.

Certain industries of minor importance to the overall estuarine zone economy assume great importance in smaller areas. The pulp-and-paper and lumber-and-furniture industries, for example, play central roles in such estuarine economic areas as the Me. Coast, the North Carolina Coast, and the Northern California Coast. In the Central Florida Gulf Coast and the Texas South Gulf Coast forestry and

and fisheries predominate. Many of these economic activities locate in various estuarine areas to take advantage of the unique natural resources of the estuarine environment found there. These activities are discussed in the next part of this chapter.

The overall economic growth of the estuarine zone will continue at a high rate in future decades. Significant concentrations of industry will continue in the relatively mature Middle Atlantic biophysical region, while significant expansion will occur in the Gulf of Mexico and Pacific biophysical regions. Marked differences will occur, however, in the smaller areas making up these biophysical regions, both in economic activity and population distribution.

FUTURE DISTRIBUTION OF ECONOMIC ACTIVITY IN THE BIOPHYSICAL REGIONS

Economic activities vary greatly throughout the estuarine zone. The principal determinants of economic activity have been the location of natural resources, historic circumstances, availability of substantial markets, and changes in technology.

The North Atlantic and Middle Atlantic Biophysical Regions

The New England marine States saw the country's first economic development. Basic resources defined the parameters of activity - forests, fish, fur, and farmlands. Shipbuilding and trade flourished around major centers of ocean-going transportation. The major metropolitan areas of Boston, New York, and Philadelphia developed

around those endeavors. Their presence led to further expansion from Massachusetts to New Jersey. Today four of the five OBE economic areas fronting on the North and Middle Atlantic biophysical regions (with the exception of the Maine coast) have become considerably less dependent on the forests and fisheries and have developed into diversified, mature economics, increasingly service-providing rather than goods-producing in character.

Maine's continuing dependence on the natural resources of fisheries and forests, and on its location in the coastal zone, is indicated by high relative concentrations of transportation equipment manufacturing excluding motor vehicles (mainly shipbuilding), paper and allied products industries; and forestry and fisheries activities. These concentrations are noticeably higher in the Maine Coastal Area than in the other four associated areas in the North and Middle Atlantic biophysical regions.

The other OBE estuarine economic areas in the North and Middle Atlantic biophysical regions exhibit economic activity that is more closely related to supplying the sophisticated and diverse demands of urban markets. All economic areas in these regions, however, are highly dependent on the estuaries for port facilities to move the goods produced within their boundaries. In the case of the Philadelphia-New Jersey-Delaware Coast, the combination of large nearby markets and adequate port facilities has combined to

stimulate a large petroleum refining and chemicals industry, even though the raw materials for those manufactures must be imported.

The Chesapeake Bay Biophysical Region

The OBE economic area of the Maryland-Virginia coast corresponds totthe Chesapeake Bay Biophysical Region. Although some of the earliest settlements occurred adjacent to the Bay and its related rivers, the area's economy has developed later than those located in the North and Middle Atlantic regions. However, the area has followed the pattern of beginning with extractive industries built upon the coastal natural resources of agriculture, forests and fisheries, and then proceeding to develop a diversified economy. In recent decades, this area has grown faster than the national average, with civilian and military government located primarily in the Washington Metropolitan Area and Hampton Roads, Newport News, respectively, providing the impetus for much of the growth. The Chesapeake Bay continues to provide an important fisheries input to the regional economy, but its importance relative to other, sometimes competing, economic activities such as primary metals, transportation services and shipbuilding has declined and is projected to continue to decline in the future.

The existence of a large steel producing plant at Sparrows Point in the Chesapeake Bay is a further example of the development of an industry highly dependent on the estuarine environment for transport by ship, but not for other natural resources.

The South Atlantic Biophysical Region

This region includes the OBE estuarine economic areas of the North and South Carolina Coast and the Georgia-Eastern Florida Coast. The economic areas in the region have traditionally been producers of raw materials in the form of agricultural products (particularly tobacco and cotton and more recently soybeans), finfish and shellfish, and forestry products. The North Carolina Coast, and to a somewhat lesser degree, the South Carolina Coast, continue to exhibit significant concentrations of economic activity in these areas. National defense activities dominate both of these areas, with Charleston being the focus for considerable Naval activity. Recreation and tourist activities dominate portions of the North and South Carolina Coastal areas, notably the Cape Hatteras, North Carolina; and Myrtle Beach, South Carolina resort areas.

The Georgia-Eastern Florida Coast area is not as dependent on the natural resources of forests and fisheries as North or South Carolina, although Savannah, for instance, is a major center for the manufacturing of paper and allied products. The importance of the land-water interface, particularly in the Florida portion of this area, is centered on its value as a retirement and recreation area. The total economy of the area has thus moved increasingly to a service-producing economy with significant growth in professional services, contract construction, amusements, and similar activities.

The Gulf of Mexico Biophysical Region

This region extends from the southern Florida Gulf Coast economic area to the Southern Texas Gulf Coast. Economic activities within this region are extremely diverse, ranging from a high dependence on agriculture, forestry and fisheries in the Central Florida Gulf Coast area to the highly industrialized petro-chemical and manufacturing economy located in the North Texas Gulf Coast and centered on the Houston-Galveston complex.

The Southern Florida Gulf Coast contains many service industries drawn to the Tampa-St. Petersburg retirement and recreation area. A high degree of specialization in contract construction in the area attests to the tremendous growth of the housing and building industry to accommodate the vast in-migration of recent years. Although forestry and fisheries is declining in this area's economy, there is a continuing relative concentration of these activities in the Southern Florida Gulf Coast area.

Central Gulf Coast area economic activity presents a picture of relatively slow growth and one which has traditionally taken advantage of the natural resources of timber, agricultural land, and marine fish which occur in the area. Forestry and fisheries are very highly concentrated into this area.

The Mississippi-Alabama-West Florida Coast are economy is highly dependent on the Federal military, especially in Pensacola, Florida.

However, the area shows great internal diversity. Mobile Bay is the center of increasing manufacturing activity and shipping. Textiles play an increasing role in this economy as well as the more traditional shipbuilding activity and fisheries centered in the Mobile Bay area. Harrison County, Mississippi, is the focus of a growing pertr-chemical complex and other heavy industry dependent on availability of crude oil, increasing developing of the inland waterway, and artificial ship-channel construction.

The Louisiana and Texas North and South Gulf Coast areas have all experienced greater-than-Nation-average growth in the recent past and are projected to continue this growth in the future. Much of this growth is attributable to the discovery and extraction of the coastal shelf petroleum deposits throughthe use of new technologies. All three economic areas show significantly high concentrations in the extractive phase of petroleum recovery (mining), the processing phase (refining), and in the production of secondary products (chemical and allied products). In contrast, the traditional importance of agriculture, forestry, and fisheries, particularly in the Louisiana and Texas South Gulf coasts, has declined.

It is interesting to note that the impact of the new petro-chemical-based economy differs markedly among these areas. The Louisiana coast experiences ample rainfall and abundant inflows of fresh water provided mostly by the Mississippi River and its tributaries. In contrast, the Texas coastal areas experience considerably less

rainfall and fresh water inflow, particularly as one mover south along the coastline. The availability of fresh and brackish water for increasing up-stream agricultural irrigation, domestic, and industrial uses will therefore be considerably different in the two coastal areas of Louisiana and Texas. This in turn will affect the desired quality and quantity of water, and increase the management problems faced by local, State and Federal Governments.

The Pacific Southwest Biophysical Region

Two of the three California OBE coastal economic areas located in the Southwest biophysical region have sustained phenomenal growth, both in population and economic activity. The manufacturing activities of both the Southern California and Central California coasts are well diversified and expanding. Most of these developments are dependent on estuarine natural resources, primarily for port facilities and for some oil extraction in the Southern California Coast. However, tremendous pressure on remaining coastal open space for housing and development already exists and will inevitably increase in the future.

The Southern California coast area is water-scarce and dependent for its supply on sources outside the area. Central California's major estuary, San Fransicso Bay, will be affected by these Southern California water demands. The California Water Plan, which calls for significant diversion of fresh water inflow, presents major problems of water quality management for this area.

The Pacific Northwest Biophysical Region

This region includes the Northern California Coast, the Oregon Coast and the Washington Coast areas. These coastal areas are relatively undeveloped except for the Portland and Seattle metropolitan areas. All three areas remain specialized in economic activities related to the ample forest and fisheries resources of this region. This region is expected to show moderate growth rates in the future, with much of this growth occurring in the two metropolitan areas of major importance. The concentration of both population and economic growth in the Portland and Seattle areas will place heavy demands on the Columbia River and Puget Sound estuarine areas, particularly as demand grows for increased port facilities and associated industry, pulp and paper manufacturing, and the processing of food and kindred products.

Table IV.4.4 summarizes in some detail the major economic indicators of individual OBE estuarine economic areas. The areas are grouped roughly by biophysical regions.

The analysis of high-water-use industries conducted by the Bureau of the Census provides a framework for analysis of the impact of present and future economic activities on the Nation's estuarine zone. In 1964, the Census of Manufactures showed that the five major water-use industries in the United States, in order of magnitude of gross water intake, were the following: primary metal

TABLE IV.4.4 SUMMARY OF ECONOMIC INDICATORS IN THE ESTUARINE ECONOMIC AREAS, SET OUT BY BIOPHYSICAL REGIONS

Coastal-Estuary Economic Area	SMSA's in the Area	Economic Growth Rate	Projected Growth Rate	Concentration and Growth of Major Industries in the Area (with location quotients of over 1.0, the National Average)	Significant High Water Use Industries
1. NORTH ATLANTIC					
Maine Coast	Portland	Less than national average (from a low comparative base level of economic activity)	Moderate increase, reaching national average	Misc. manufacturing (2.2) +Trans. equipment, excluding motor vehicles (3.3) Food and kindred products (1.2) Paper and allied products (3.6) -Textiles (2.0) -Lumber and furniture (1.6) *Forestry and fisheries (10.6)	Paper and allied products
Massachusetts-Rhode Island Coast	Boston, Lawrence-Haverhill, Lowell, Brockton, New Bedford, Fall River and Providence-Pawtucket-Warwick	Less than national average (from a high comparative base level of economic activity)	Slightly declining but continuing above the national average	Misc. manufacturing (2.4) +Electrical equipment (2.3) -Textiles (2.3) Apparel (1.5) +Food +Non-Electrical machinery *Forestry and fisheries (1.8)	Total manufacturing; Textiles (though the importance of this industry is declining sharply)
2. MIDDLE ATLANTIC					
Connecticut Coast	New London-Groton-Norwich, Meriden, New Haven and Waterbury	Less than national average (from a high comparative base level of economic activity)	Slightly declining but continuing above the national average	+Misc. manufacturing (2.6) +Fauricated metals & ordnance (3.3) +Trans. equipment, excluding motor vehicles (3.7) Non-Electrical machinery (1.4) *Primary metals (1.8) Paper (1.4) Chemicals (1.3)	Total manufacturing; Chemicals; Paper; Primary Metals
New York-Northeast New Jersey	Bridgeport, Norwalk and Stamford, Conn., and New York, New York & Jersey City, Newark and Paterson-Clifton-Passaic, New Jersey	Less than national average (from a high comparative base level of economic activity)	Slightly declining, but likely to remain as the focal point of American economic activity in the future	Apparel (2.9) +Mis. manufacturing (1.4) +Electrical equipment (1.4) -Printing and publishing (1.7) Food *+Chemicals (1.5) +Other transportation services (2.2)	Chemicals; Textile mill products
Philadelphia-New Jersey-Delaware Coast	Philadelphia, Wilmington, Delaware & Atlantic City, New Jersey	Less than national average (from a high comparative base level of economic activity)	Slightly declining, but continuing above the national average	+Misc. manufacturing (1+) +Electrical equipment (1+) +Chemicals (2.9) -Apparel (1+) +Food (1+) +Petroleum refining (2.6) Other transportation services (1+)	Total manufacturing; Food; Chemicals; Paper and allied products and petroleum refining
3. CHESAPEAKE BAY					
Maryland-Virginia Coast	Baltimore, Washington, D.C. and Richmond, Newport News-Hampton Roads and Norfolk-Portsmouth, Virginia	Greater than national average	Moderate increase, maintaining relative position of wealth versus the national average	+Government Public Admin. (2.9) Armed Forces (3.2) +Food +Trans. equipment, excluding motor vehicles (1.5) +Printing and publishing (1.2) Primary metals *-Forestry and fisheries (2.2) Other transportation services (1.3)	Primary metals

TABLE IV.4.4 SUMMARY OF ECONOMIC INDICATORS IN THE ESTUARINE ECONOMIC AREAS, SET OUT BY BIOPHYSICAL REGIONS (continued)

4. SOUTH ATLANTIC						
	North Carolina Coast	Wilmington, North Carolina	Slightly greater than average (from a low base level of economic activity)	Moderate increase, but continuing below the national average	Armed Forces -Agriculture -Lumber and furniture (2.7) Food -Apparel -Textiles -Forestry and fisheries (6.1)	Food, Textiles, Paper and paper products
	South Carolina Coast	Charleston, South Carolina	Greater than average (from a low base level of economic activity)	Moderate increase, but continuing below the national average	Armed Forces -Agriculture +Transportation equipment, excluding motor vehicles (3.3) -Lumber and furniture (2.0) Paper and Allied Products (2.8) +Forestry and fisheries (3.4)	Paper and paper products
	Georgia-Eastern Florida Coast	Savannah, Ga., Jacksonville, West Palm Beach, Ft. Lauderdale-Hollywood & Miami, Fla.	Considerably greater than the national average	Considerable increase, maintaining wealth position equal to that of the nation.	+Services Food Misc. manufacturing Paper (1.4) Forestry and fisheries (1.6)	Paper and paper products
5. Gulf of Mexico						
	Southern Florida Gulf Coast	Tampa-St Petersburg	Considerably greater than average	Considerable increase, maintaining a wealth position somewhat less than that of the nation	+Services Contract construction (1.3) Misc. manufacturing +Food (1.1) -Forestry and fisheries (2.4)	Food and kindred products
	Central Florida Gulf Coast	---	Greater than national average (from a low comparative base level of economic activity	Considerable increase, but remaining below the national average	Government Armed Services (5.2) +Paper and paper products (7.6) -Lumber and furniture (2.3) Food and kindred products -Forestry and fisheries (18.6) -Agriculture	Paper and paper products, Food and kindred products
	Mississippi-Alabama-West Florida Coast	Pensacola, Florida and Mobile, Ala.	Greater than national average (from a low comparative base level of economic activity)	Moderate increase, increasing to national average	+Government Armed forces +Paper and paper products (4.1) +Transportation equipment, excluding motor vehicles (1.9) -Food and kindred products +Textiles (1.3) Forestry and fisheries (5.2)	Paper and paper products, Textiles
	Louisiana Coast	New Orleans, Lafayette and Lake Charles	Greater than national average (from a relatively high comparative base level of economic activity)	Relatively stable, maintaining a level somewhat less than that of the nation	Food and kindred products (1.5) +Petroleum refining (4.3) +Chemicals (1.1) Transportation equipment, excluding motor vehicles +Mining -Forestry and fisheries (4.5) -Agriculture +Other transportation servies (3.6)	Petroleum refining, Chemicals, Food and kindred products

TABLE IV.4.4 SUMMARY OF ECONOMIC INDICATORS IN THE ESTUARINE ECONOMIC AREAS, SET OUT BY BIOPHYSICAL REGIONS (continued)

Texas North Gulf Coast	Houston, Beaumont-Port Arthur-Orange, Galveston-Texas City.	Considerably greater than the national average (a comparatively recent phenomenon)	Petroleum refining, Chemicals and allied products, Primary metals	+Mining (mainly petroleum)(2.9) +Petroleum refining (13.0) +Chemicals (3.1) +Non-Electrical machinery (1.3) Other transportation services (1.9)	Petroleum refining, Chemicals and allied products, Primary metals
Texas South Gulf Coast	Corpus Christi, Brownsville-Harlingen-San Benito	Considerably greater than the national average (from a low comparative base level of economic activity)	Moderate increase, but continuing below the national average	-Agriculture Food (1.1) +Primary metals(1.1) +Chemicals (1.5) +Petroleum refining (3.0) -Forestry and fisheries (5.6) +Mining (3.4)	Chemicals and allied products; Petroleum refining; Primary metals
6. PACIFIC SOUTHWEST					
Southern California Coast	Los Angeles-Long Beach, San Diego, Santa Barbara, Oxnard Ventura and Anaheim-Santa Ana -Garden Grove	Considerably greater than national average (from a relatively high base level of economic activity)	Moderate increase, maintaining a position of wealth relative to the nation	+Transportation equipment, excluding motor vehicles (4.0) +Fabricated metals and ordnance (1.8) +Electrical equipment (1.5) +Misc. manufacturing +Non-Electrical machinery +Food and kindred products +Services +Petroleum refining (1.5)	Total manufacturing activity; Food and kindred products, Petroleum refining
Central California Coast	San Francisco-Oakland, Vallejo-Napa, Salinas-Monterey and San Jose	Greater than national average (from a relatively high base level of economic activity)	Moderate increase, maintaining a position of wealth relative to the nation	+Government +Services Food (1.3) +Fabricated metals & Ordnance (1.3) Electrical equipment Printing and publishing (1.1) +Other Transportation Services (1.9) Petroleum refining (1.8)	Food and kindred products
Northern California Coast	---	Greater than the national average	Moderate increase, maintaining relative wealth of the area versus the national average	Lumber and Furniture (19.8) Food and kindred products Forestry and fisheries (11.6)	--
Oregon Coast	Portland, Eugene	Somewhat greater than the national average	Moderate increase, equal to that of the national average	Lumber and Furniture (7.0) Food and kindred products +Paper (2.7) Forestry and fisheries (4.2) Other transportation services (1.4)	Paper and allied products
Washington Coast	Seattle-Everett, Tacoma	Somewhat greater than the national average	Moderate increase, maintaining relative wealth of the area versus the national average	+Trans. equipment, excluding motor vehicles (6.7) -Lumber and furniture (3.0) Food and kindred products Printing and publishing Paper and allied products (1.7) Forestry and fisheries (3.7) Other transportation services (1.8)	Paper and allied products

+: Fast Growth Industries
-: Slow Growth or declining in regional importance

*: Those economic activities listed under the solid line are concentrated in the Area, but are NOT major contributors to Area employment.

industries; chemicals and allied products; paper and allied products; petroleum and coal products; and food and kindred products.

Ranked in order of brackish water use (which may include use of estuarine water), chemicals and allied products were overwhelmingly the highest water user, nearly equalling the totals of the other four highest users, which were the following: petroleum and coal products; primary metal industries; paper and allied products and food and kindred products. The two industries that exhibited significant increases in brackish water use between 1954 and 1964 were chemicals and allied products, and primary metals.

SECTION 3. TRENDS IN SELECTED ACTIVITIES ASSOCIATED WITH THE ESTUARINE ZONE

The discussions in the preceding sections give some indication of the pressures placed on the estuarine resources in recent years and those that may be expected in the future. This section presents the discernible trends of some specific activities associated with the estuaries. Where possible, projections are made of the likely results of these trends.

For convenience of presentation and examination, different activities are discussed separately; however, it must be emphasized that these activities are closely interrelated and often place additive and conflicting demands on the estuarine environment. In short, because these activities all take place in the limited area of the landwater interface, and affect the land frontage, water, and biota of the zone, problems of management are inescapable.

The activities selected for detailed attention are those which have a particularly close relationship to the resources that occur in the estuaries, open coastline, and near-shore waters. Other activities that are found in the estuarine zone, but are not directly tied to the natural resources existing there, are given less attention. The concepts of primary, secondary, and marginal activities (Figure IV.3.1) are used with these definitions:

(1) Primary activities are those uses which by their nature are locationally tied to the estuarine zone;

(2) Secondary activities are those uses that are closely associated with primary activities and as a consequence have a significant tendency to locate in the estuarine zone; and

(3) Marginal activities are those uses which are not directly tied to the estuary zone, but which tend to be found in areas of urban-suburban development.

Harvesting finfish and shellfish for food and other uses is an example of primary activity associated with the estuary zone, while plants constructed to process the catch denote secondary activities. Marine waterborne commerce is directly tied to the estuary port system and is thus considered a primary activity. The naval arm of the national defense capability is likewise firmly linked to existing ports and harbors and is thus a primary activity. Specialized facilities and provision of logistical support for these primary commercial shipping and naval activities are secondary activities. Industries which require frontage on navigable waters to receive or distribute bulk raw materials and/or processed goods by ship are primary activities. Examples of this type of industry are petroleum transportation (often closely tied to secondary processing activities),

export of bulk commodities such as lumber and grain products, some primary metal refining, and shipbuilding.

Many other activities compete for locations in the estuary zone, drawn by the inflow of raw materials, by extensive markets, or by the availability of transportation networks in significant protions of the zone. Examples of secondary activities which are located in the estuarine zone are pulp and paper mills, fossil or nuclear power plants -- where location must be balanced with the distance to consumers of energy -- chemical and food processors, and primary metals refineries.

Despite the fact that the estuarine environment supplies relatively unique resources which attract many primary and secondary activities, the greater part of economic activity, particularly in the relatively mature economies of the Northeast, Middle Atlantic and West coasts, is not directly dependent on the natural resources of the estuarine environment. The service sectors of the economy dominate most of these marginal activities and range from garbage collection to construction of office buildings. Many other marginal activities are drawn to the land-water interface for aesthetic reasons, such as restaurants, hotels and specialty shops. The resulting mix of many economic activities, with significant variations in proportional make-up of primary, secondary and marginal activity, characterize

the dominant urban-suburban environment which exists and will increase in the estuarine zone and coastline of the Nation.

Trends and projections for marine fisheries, transportation and national defense, marine mining and processing, recreation, and waste discharge are presented here. Where appropriate, the discussion of these subjects is related to the biophysical regions and OBE estuarine economic areas.

MARINE FISHERIES

The Nation's fishing industry has been widely characterized as relatively undeveloped in management and operation, inferior to the competing fishing fleets of other nations in technology, undercapitalized, and relatively weak in respect to both the national economy and to foreign competition. This consensus of opinion is supported by numerous comparative statistics.

The industry has grown relatively slowly in productivity over the years. From 1925 through 1966, the quantity of catch increased by only 60 percent. During the same period, the rise in the amount paid to fishermen for their catch was only slightly higher, increasing something less than 100 percent. In fact, the average annual catch per fisherman has remained below the 1957-1959 average since 1964.

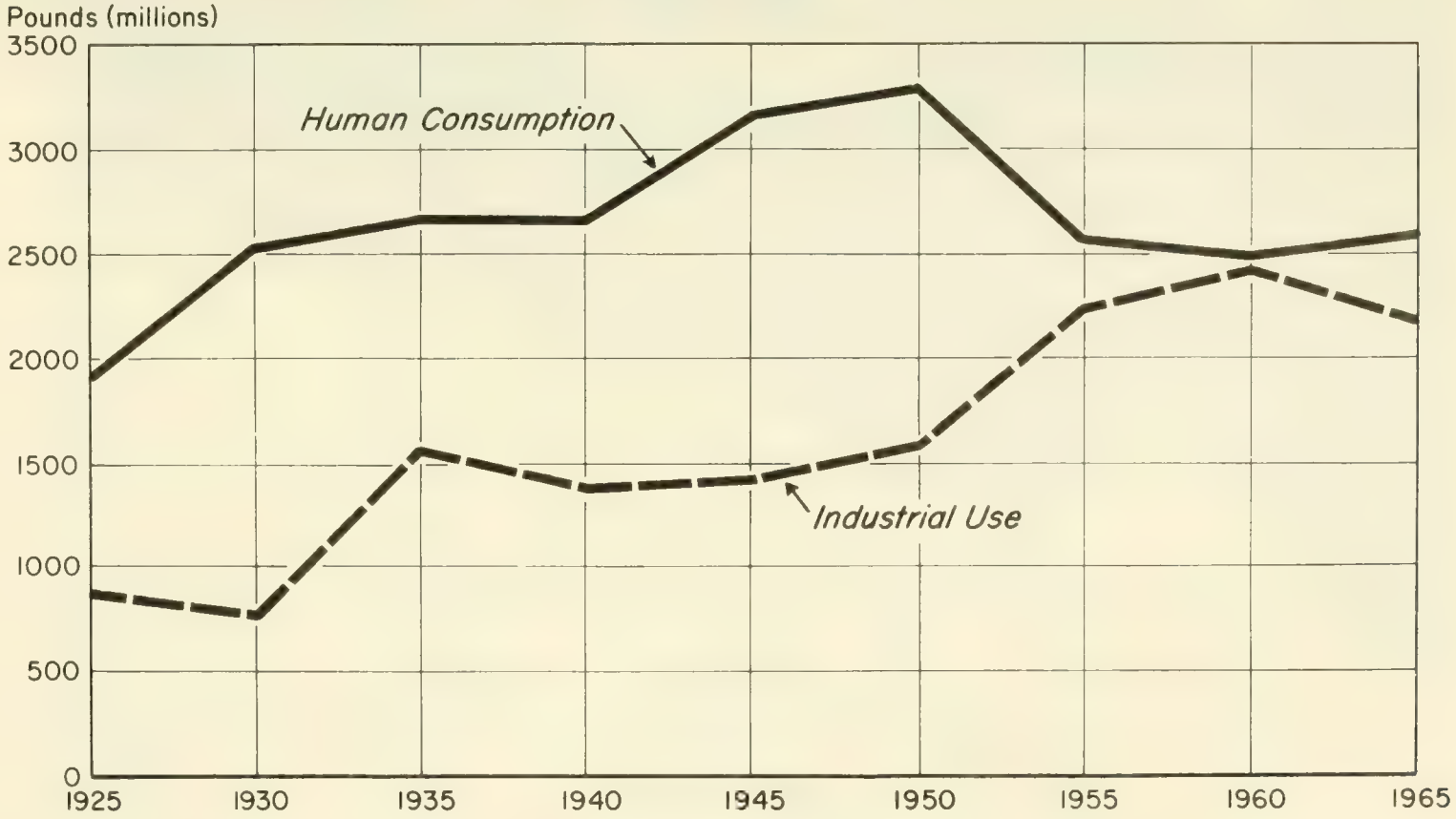
The Industrial Fishery

Industrial uses of commercial fish, rather than human consumptive uses have accounted for most of the increase in tonnage in the recent past, as indicated in Figure IV.4.11. This trend is particularly evident in the more recent period between 1961 and 1966. Industrial uses of marine fish are primarily for fish oils, fish solubles and fish meal. These basic products are used mainly for industrial processing, pet food, agricultural feed (particularly for chickens) and fertilizers.

The primary species caught for industrial use is the menhaden, an estuarine-dependent fish. Productive areas for this fish have been the Middle Atlantic, Chesapeake, South Atlantic and Gulf of Mexico biophysical regions. Production in the Middle Atlantic region has decreased markedly in recent years, and the catch in the Chesapeake Bay has fluctuated. Fishing pressure for menhaden in all regions has intensified, and may have reached the point of overharvest in some localized areas. This pressure has continued despite declines in the wholesale price for fish meal partly brought on by foreign competition, particularly from anchovies from the Humboldt Current grounds off Peru. Figure IV.4.12 indicates the growing foreign share of the industrial fish catch.

Figure IV.4.11

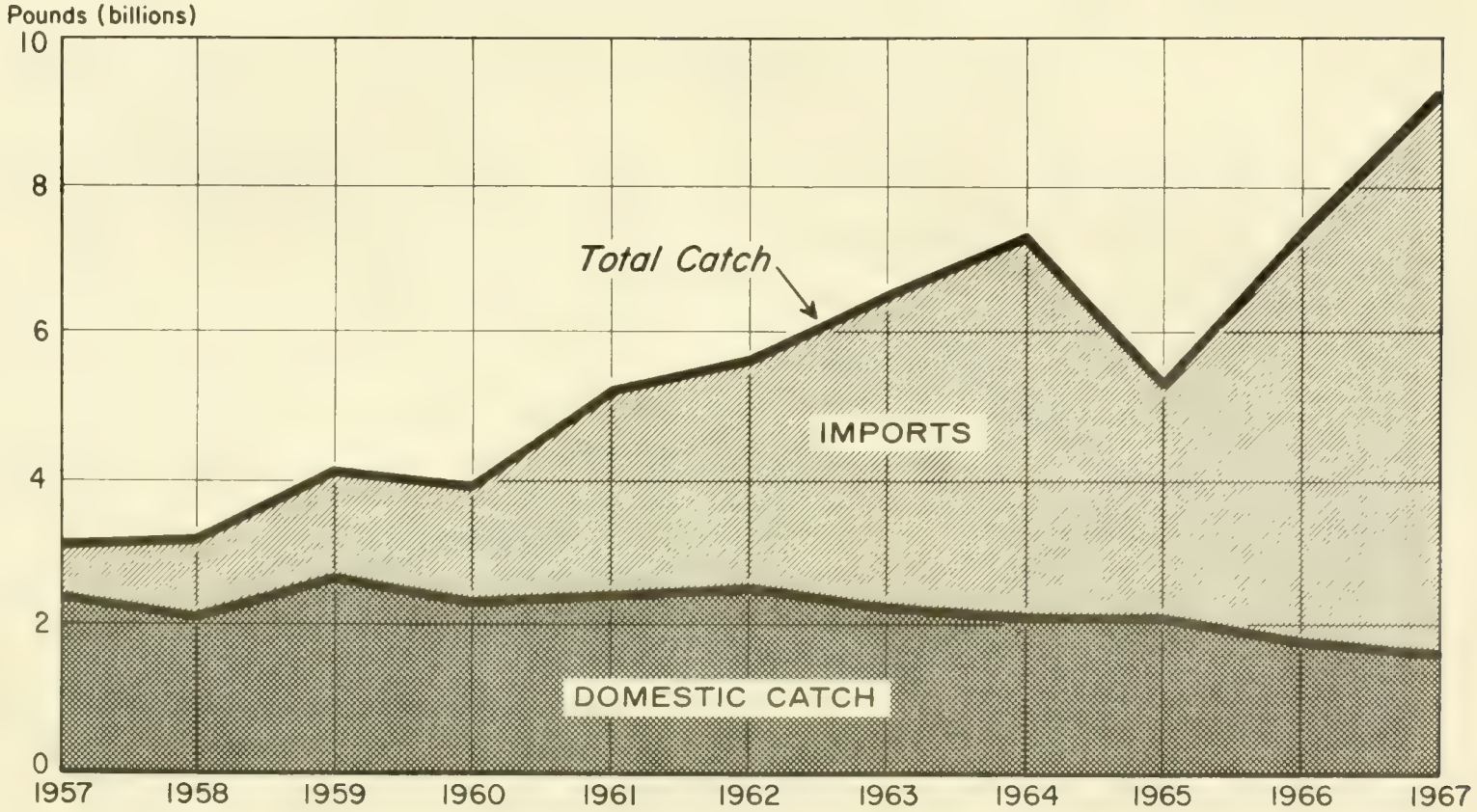
HUMAN CONSUMPTION AND INDUSTRIAL USE OF DOMESTIC FISH CATCH, 1925-1965



Source: Bureau of Commercial Fisheries.

Figure IV.4.12

FOREIGN AND DOMESTIC SHARES OF TOTAL INDUSTRIAL FISH CATCH, 1957-1967



In 1958, imports of industrial fishery products accounted for 35 percent of the total United States supply; in 1967, imports accounted for 82 percent of the total. This increasing share of imported industrial fish products contributes to the balance of payments problem in the national economy as well as directly affecting the economic base of the domestic fishing industry.

It must be noted, however, that increased harvesting of industrial fish is ultimately dependent on existing renewable supplies of the resource. Although some sizeable stocks of under-utilized species exist, such as the thread herring in the Gulf of Mexico, other stocks may be over-fished, now or in the future. Further degradation or destruction of the estuarine nursery grounds for menhaden could well reduce or eliminate this major domestic source of industrial fish.

The Edible Commercial Fishery

Despite the growth on the industrial fish sector, edible fish continue to dominate the overall fisheries market in terms of value, as Table IV.3.4 indicates.

Shrimp

Penaeidean shrimp, the most valuable commercial fish resource, are dependent upon the estuary for nursery grounds and are then harvested

in coastal shelf waters. Almost all domestic harvesting of this shellfish occurs in the Southern South Atlantic and Gulf of Mexico biophysical regions. Particular estuarine economic areas that support this fishery and allied processing are the Georgia-Eastern Florida Coast, the Louisiana Coast, the Mississippi-Alabama-West Florida Coast and the Texas North and South Gulf Coasts.

Recent and projected trends show a strong and increasing demand for shrimp although prices have increased rapidly. The ability to supply these increasing demands in the future is dependent, to a great extent, on the continuing supply of domestic shrimp. It is estimated that the shallow water shrimp fishery is already fully utilized and perhaps over-fished in the traditional South Atlantic and Gulf of Mexico grounds. While the deep water shrimp supplies are estimated to be large and are relatively untapped, there are considerable technological problems in locating and harvesting these shrimp.

The continued existence of domestic shrimp to meet rising market demands is uncertain. Recent declines in shrimp landings have been noted in estuarine areas of relatively little industrial and population pressure and in areas of considerable economic and population concentration. For example, in Florida's Apalachicola Bay, the shrimp fishery experienced a dramatic decrease in the short period

between 1964 and 1967. The 1967 catch was less than 17 percent of the 1964 landings. Nearby St. George Sound experienced a similar decline during the same period. The decline in local supplies of shrimp forced Apalachicola fishermen to extend their operations to the Tortugas Area of Florida, which not only increased their operating costs, but -- more significantly -- added to the heavy pressure already applied to the Tortugas shrimp fishery.

Galveston Bay, a steadily growing population and industrial center, has been a prime nurse ground for shrimp and a major area of shrimp harvesting and processing. These primary and secondary fishery activities are threatened by the degradation of the Galveston estuarine environment by industrial and municipal pollution, by dredging and filling, and by decreases in the quantity and quality of freshwater inflows. Although market demand and prices rose steadily from 1962 through 1966, and fishing pressure increased, the total Galveston catch declined drastically from 4,192,900 pounds in 1962 to 1,941,000 in 1966. Although a direct causal relationship between estuary degradation and this decline in catch cannot be demonstrated at this time, it is reasonable to conclude that the cumulative effect of degradation acts to reduce available supplies of shrimp.

Oysters

The record of the oyster industry in the United States is a continuing story of depletion in absolute quantity and decline in the usefulness of remaining beds. Declines have taken place in nearly all estuary areas that naturally supported oyster populations. Depletion has occurred for many reasons, both natural and man-induced.

Natural catastrophes have depleted the oyster beds over time. The hurricane of 1954 in Narragansett Bay, for example, is considered the prime factor in the destruction of beds and the decline of the secondary processing industry in that location. By 1956 the oyster harvest from Narragansett Bay had declined to 31,000 pounds, from 252,000 pounds in 1953. In 1957, the last remaining oyster dealer went out of business.

Most of the reduction in domestic oyster production, however, can be attributed to man's activities in the estuaries. Examples of the diminution or extinction of this resource are many. New Jersey's Raritan Bay, an outstanding producer of oysters for the New York market in the nineteenth century, is now almost barren of this shellfish, mainly due to municipal and industrial waste discharge. A study in Shelton, Washington, indicated that sulphite waste discharge from paper pulp manufacturing almost surely brought about a serious decline in the oyster population.

Many areas of oyster production for human consumption are closed because municipal wastes contaminate oysters with bacterial matter.

Silting due to dredge operations has appreciably diminished the quality of many former oyster-producing areas. The silt may actually smother the beds, or may so seriously disturb the estuary floor as to cause deleterious effects from lowered amounts of dissolved oxygen. This process, which has been observed in parts of Galveston Bay, produces hydrogen sulfide and releases concentrated amounts of toxic chemicals in bottom sediments.

The decrease in production and consumption of oysters due to natural or man-induced causes is exacerbated by changes in consumer preference, lack of mechanized shucking and packaging procedures, and increasing labor costs. Perhaps the most difficult problem is presented by the legal labyrinth surrounding ownership and use of oyster beds. Management and sound overall economic use of the oyster resource is almost impossible under present institutional constraints which range from public ownership in Massachusetts to a tangle of leasing and private ownership in such areas as Georgia, the Chesapeake Bay, and James River estuaries.

The future of a viable oyster industry, and the continued availability of a delicate and nutritious food, is thus linked not only to the quality of the biophysical environment, but to the workings of the economic and institutional environment as well.

Anadromous Fish

Landings of anadromous fish, particularly those of economic importance such as the salmon and shad, have declined in numbers, while retail markets have generally shown a steady improvement.

The diminution of the continental salmon fishery provides a classic example of the damage inflicted on fisheries by biophysical modification. As dam-building, lumbering, and other kinds of man's activities increased, the once-abundant salmon catches declined. The Atlantic Salmon has almost completely disappeared from the east coast. On the west coast, reduction in the quality and quantity of freshwater, sedimentation in spawning areas, pollution of the transitional zones in estuaries, and heavy fishing pressure by both sport and commercial fishermen have combined to reduce the once-flourishing salmon industry.

Most of the domestic catch now comes from salmon dependent on the streams, rivers and estuaries of Alaska, since that State is for the most part free of the physical and biological modifications made by man in the other Pacific Coast States. Growth of logging, oil, natural gas, and hydroelectric activities may alter this situation drastically in coming decades. Even without these modifications, which have little-known effects on the possible sustained yield of Alaskan Salmon, this fishery faces serious economic and institutional

problems. Fishing pressure is rising significantly because of increased numbers of fishermen and improved harvesting technology, while catch per fisherman has declined greatly. Increases in market price sustained this odd circumstance, as Figure IV.4.13 shows.

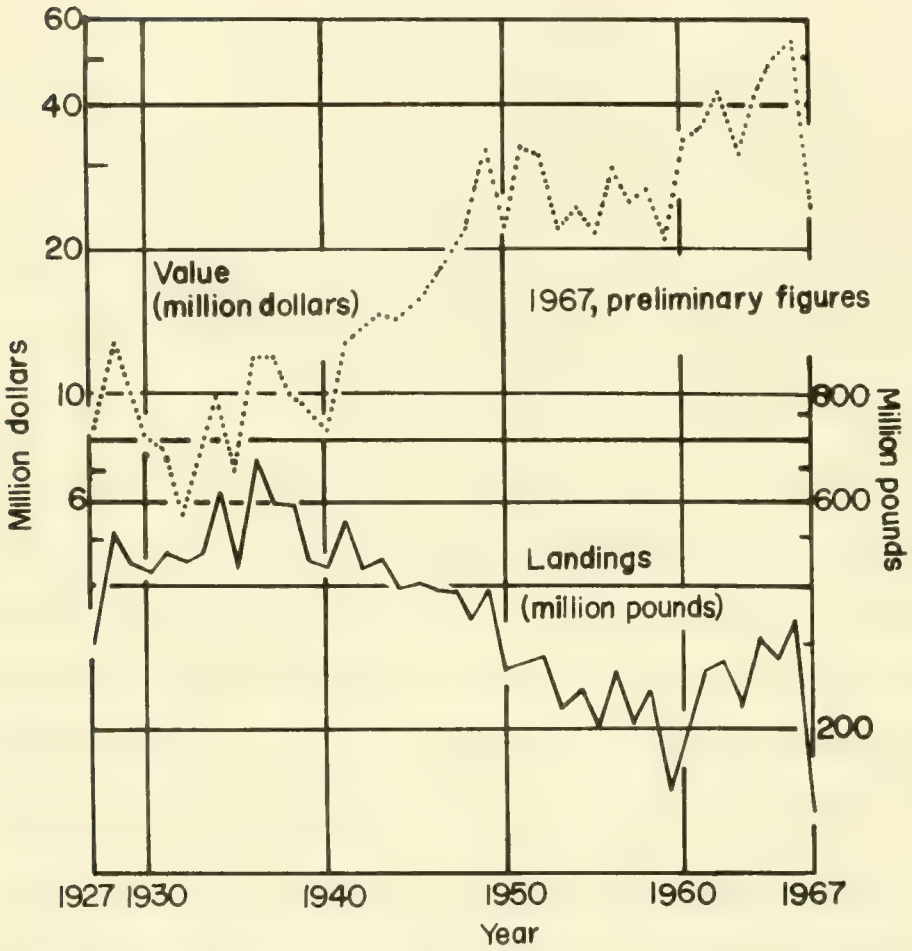
Future Prospects

Examples of the historical decline and projected pressures on the domestic commercial fishery could be multiplied many times. The market demand for fishery products is growing and is projected to rise sharply in the near future, but the amount of that market which will be supplied by imports is not yet clear.

It is the conclusion of many experts in the field that a harsh choice must be made in the near future: either the management of the Nation's estuarine resources will be substantially strengthened, institutional constraints relieved, and the trend toward degradation of the estuarine environment stemmed, or the supply of commercially valuable finfish and shellfish to meet rising demands will diminish.

Mariculture, the manipulation of the estuarine or marine environment to increase production of commercial species, is often cited as a method to overcome the depletion of natural stocks and fill increasing market demands for fish products. The ability of artificial culture to significantly increase yields has been

FIGURE IV.4.13 TOTAL ALASKA SALMON CATCH
(POUNDS & VALUE), 1927-67



Source: Bureau of Commercial Fisheries

proven in countries such as Japan where shrimp, oyster, and certain finfish are raised on a profitable basis. However, the economic use of mariculture is in its infancy in the United States. Although the ultimate impact of aquaculture practices would appear great, increasing yields from five to as much as twenty times, the present economic and social climate would seem to indicate that the impact of mariculture will be relatively slight in immediate future decades. When other ancillary values are added, it would appear that proper management of the natural estuarine environment is a preferable course of action both to preserve and perhaps enhance the production of fish and maintain the quality of this unique environmental resource.

COMMERCIAL AND NATIONAL DEFENSE TRANSPORTATION

Commercial

An environment favorable to transportation has been one of the most significant historical factors in coastal and estuarine development. Settlements originated at the sites of coastal harbors and at the mouths of rivers because of the accessibility of these areas to trading vessels. The commerce which passed through these centers encouraged further growth and development. The coastal and estuarine areas also saw rapid development of air, rail, and highway systems because the main demand was located there

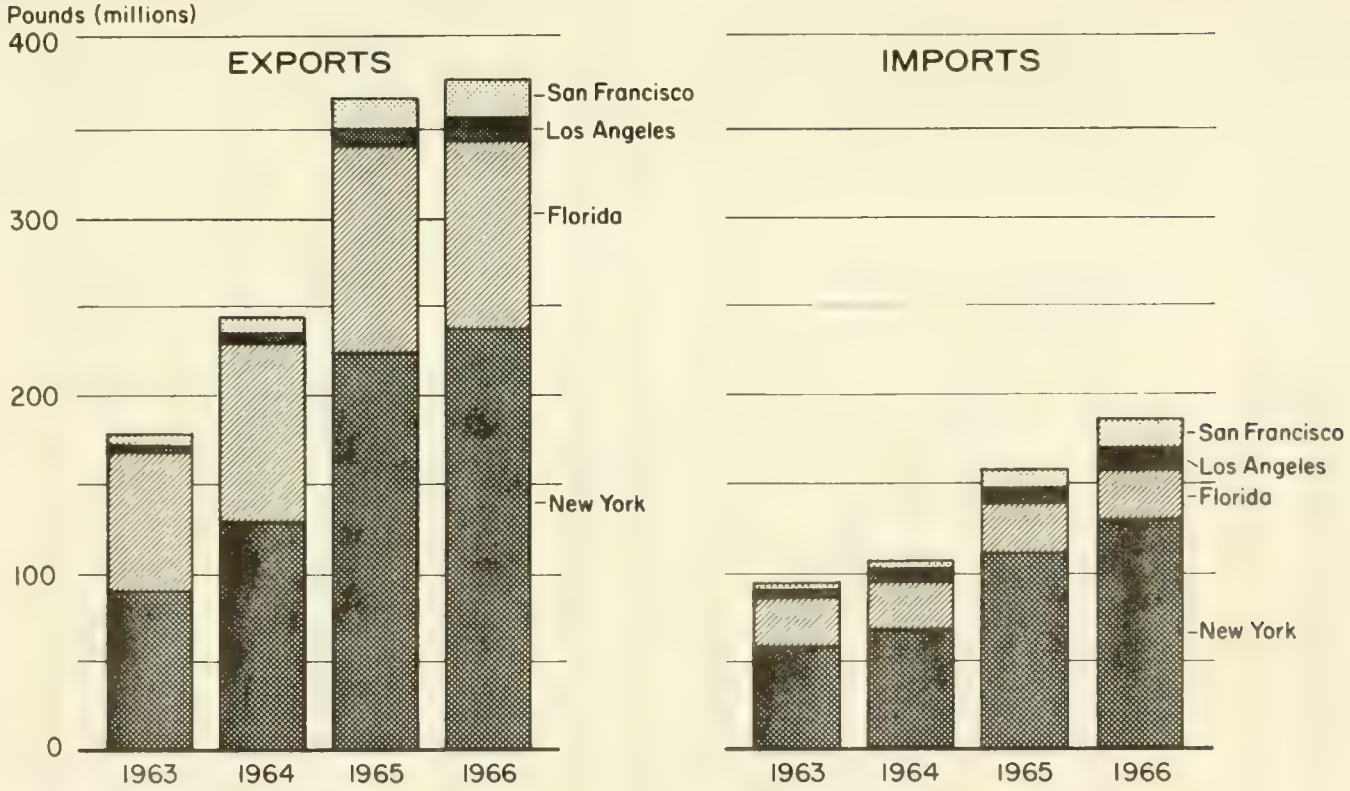
and the terrain presented few obstacles. Connecting links were needed between the coastal trade centers and the hinterlands, and the level land available along the coasts, bays and rivers was the natural location for railroads and highways for both engineering and economic reasons. Airports also require large tracts of level land, and a waterside location affords the benefits of unobstructed and unpopulated approach zones. This concentration in coastal and estuarine centers has continued as these areas have maintained their growth and thereby further stimulated the maximum utilization and exapnsion of transport facilities.

Airborne commerce has experienced considerable growth. Some statistics are available to relate it to estuarine locations. Figure IV.4.14 gives some historical data on airborne import and export commerce by coastal Customs Districts. Airport location on or near an expanse of water is desirable because it affords unobstructed approaches and reduces noise problems. Airports are presently located in estuarine areas in Boston, New York (both Kennedy and La Guardia), Washington, Norfolk, San Diego, San Francisco and Oakland.

A further element which will almost certainly affect the estuarine zone is the development of new ports. For example, if the proposed free port in Maine becomes a reality there will be a rapid proliferation of all types of commercial transportation to service that port

Figure IV.4.14

AIRBORNE EXPORTS AND IMPORTS AT COASTAL CUSTOMS DISTRICTS, 1963-1966



Source: Department of Commerce, Statistical Abstract of the United States; 1966 and 1967.

area and to provide a network for distribution. Since major refinery operations are part of the proposed plans, this development will include pipelines and associated petro-chemical facilities, and other modes of land transport. Such a free port could have far-reaching effects on the present distribution of cargo tonnages at east coast ports as well as develop an estharine area which is now relatively pristine.

Another factor which could significantly affect the trade distribution of all ports is the development of the super-tanks and larger dry cargo vessels. These carriers require up to sixty-foot channel and berthing depths. This will call for an enormous dredging operation in most ports, where maximum dredged channel depth now is around forty feet. Some places, like New York, have already been dredged to bedrock level, so blasting would be necessary to go deeper. An alternative solution is to establish offshore docking facilities for the super-ships and bring their cargoes ashore through pipelines or in lighter-type ships. The bottom clearance requirements of these ships are considerably smaller, which would mean far less dredging for channel maintenance. However, the current world merchant fleet will no doubt continue to operate for at least another 20 years, which means that channels would have to be maintained at least until this generation of ships has been phased out.

It has also been suggested that a decrease in the number of ports might prove more economical in the handling of the super fleet because

of its enormous cargo capacity. Improved off-loading technology and larger warehouses will be necessary to handle the increased tonnage, and it would be inefficient to develop a whole network of these facilities, some of which might lie idle part of the time. Furthermore, many smaller ports probably could not generate enough demand to warrant development of super ship capabilities.

The expansion of land transportation can be expected to parallel port development in the future as it has in the past. Pipeline construction will develop concurrently with oil production--probably at a rapid rate since the demand for natural gas and petroleum products is expected to triple over the next thirty years. The future of rail transport is difficult to assess, not so much because of demand factors but because the roads (particularly in the East) are undergoing a period of administrative restructuring and a consolidation of service.

The Houston-Galveston Bay complex demonstrates how a good harbor can encourage the growth and development of an area and begin a demand spiral that leads to more intensive utilization of the harbor and the development of other transport facilities. The Port of Houston is now the third largest U.S. seaport in terms of total tonnage moved. In 1963, approximately one-third of Houston's economy was linked to the ship channel, the port and the resultant industry. Total investment flowing from the port facilities and related industries exceeded $2.5 billion that year. The dredging of the Houston Ship Channel and the development of cargo facilities has thus been of major consequence in the development of this area.

Table IV.4.5 shows the significance of transportation and its concomitant, wholesale trade, for the Houston-Galveston Bay area for the years 1956 and 1967. The Port of Houston is served by six trunkline railroads, 38 motor freight carriers, 8 barge lines, 11 export packers, 35 freight forwarders, 19 stevedoring companies, and a large number of marine outfitters and ship chandlers. More than 100 steamship lines offer service to all free-world ports. Future demand for all types of transportation is expected to increase as the population grows and industry expands.

The San Francisco Bay Conservation and Development Commission has done an excellent case study of the transportation pressures being exercised in its estuarine area. San Francisco was founded as a port city, and shipping is still of primary importance to the entire economy of the Bay area. In addition to the economic impact of the shipping industry itself, there are many other businesses and industries that have been drawn to the region because of the availability of water transport. In 1965, Checchi and Company estimated that 50,000 jobs were attributable to general-cargo shipping and industries dependent on shipping. This represented a payroll of about $820 million.

By tonnage, the principal cargo passing through the San Francisco Bay is petroleum. This tonnage is expected to increase significantly in the future, and bring with it deep draft tankers with drafts as much as 60 feet. At this time, however, there are no reliable estimates of the impact of this future increase in San Francisco port traffic, nor

TABLE IV.4.5

Transportation-Wholesale Trade Industries
Bay Area, 1956 and 1967

	1956	1967
EMPLOYMENT		
Total in Study Area	384,891	608,865
Total in Transportation-Wholesale Trade	62,790	96,550
Transportation-Wholesale Trade as Percentage of Total	16.3	15.9
TAXABLE PAYROLLS (millions)		
Total in Study Area	$1,535.6	$3,053.6
Total in Transportation-Wholesale Trade	255.6	637.2
Transportation-Wholesale Trade as Percentage of Total	16.7	18.2
NUMBER OF FIRMS		
Total in Study Area	25,465	34,187
Total in Transportation-Wholesale Trade	2,977	4,269
Transportation-Wholesale Trade as Percentage of Total	11.7	12.5

Source: County Business Patterns, 1956, 1967.

are there reliable methods to measure the conflicting values and costs presented by this pehnomenon.

NATIONAL DEFENSE

The use of estuarine and coastal ports has always been an essential need of the national defense system for the movement of weapons, troops, and supplies to and from overseas bases and operations zones. Table IV.4.6 itemizes amounts of military cargo and passengers transhipped by area for two recent years. Tons and dollar value of cargo went up appreciably from FY 1966 to FY 1967, while numbers of passengers decreased. The impact of the Vietnam war can be seen in the comparison of figures for the Eastern and Western areas for the two years. However, it is a primary item of Defense policy that facilities be available for use in all coastal areas to meet particular military logistics requirements at any time.

Future demands for the use of estuarine and coastal areas by the Department of Defense are difficult to project since they will vary greatly according to the state of international affairs and the impact of technological developments. The Office of Business Economics has regarded military employment as a constant after the year 1980 because of this lack of predictability. The examples given in Chapter 3 of the impact of Naval activity on Narragansett Bay and San Diego Bay give at least a general idea of the magnitude of present and future military activities in the Nation's estuaries.

TABLE IV.4.6

Military Cargo And Passengers Transhipped through Continental United States Water Ports*

Part I Cargo Areas	FY 1966		FY 1967	
	Measurement Ton (a) thousands	Dollars millions	Measurement Ton (a) thousands	Dollars millions
Total all areas	15,965.4	134.0	20,835.5	184.6
Eastern area	7,777.3	52.0	8,973.5	66.8
Atlantic ports	5,723.5	39.9	6,243.3	49.1
Gulf ports	2,030.0	12.0	2,635.5	17.0
Western area	8,188.1	82.0	11,862.0	117.8
N. Pacific Coast (Wash.-Oreg.)	1,625.2	14.5	3,275.5	29.1
S. Pacific Coast	6,562.9	67.5	8,586.5	88.7

Part II Passenger	FY 1966		FY 1967	
	Passengers, thousands	Dollars, thousands	Passengers, thousands	Dollars, (b) thousands
Total all areas	213.7	480.5	120.5	366.6
Eastern area	121.2	365.9	28.6	171.8
Atlantic ports	120.0	361.2	27.8	166.4
Gulf ports	1.2	4.7	0.8	5.4
Western area	92.5	114.6	92.2	194.8
N. Pacific Coast (Wash.-Oreg.)	(C)	(C)	10.2	21.6
S. Pacific Coast	92.5	114.6	82.0	173.2

* With the exception of the Great Lakes

Source: Quarterly progress report. Fourth Quarter FY 1967. RCSDD-IL (Q) 493. Military Traffic Management and Terminal Service. Washington, D. C.

(a) One measurement ton = 40 cu ft.

(b) Dollars amounts represent cost, not revenue, which is computed on predetermined billing rates.

(c) No movement reported.

ESTUARINE MINING AND PROCESSING

Actual extraction of both hard and soft minerals from the estuaries is presently limited. By far the most valuable and potentially profitable mining activities in the estuary areas are petroleum extraction, gas and sulphur recovery, and sand, gravel, and shell dredging. It is important to note that the primary activity of extraction, with the exception of sand and gravel dredging, has had relatively little effect on the estuarine environment. Such secondary activities as petroleum refining, transport by pipeline or ship, and petro-chemical processing have had much greater impact. Finally, the marginal activities which grow up to support the populations drawn to areas of heavy petroleum extraction and secondary industry also place a heavy burden on the quality of the estuarine zone.

Petroleum (oil and gas) dominates present and projected mining activity in the offshore regions of the United States, accounting for over 84 percent of offshore mineral production in 1966. Offshore sources supply a relatively small, but rapidly increasing, share of the total domestic oil output.

As Table IV.4.7 illustrates, offshore production of petroleum has grown steadily in the past decade, rising from less than 3 percent of total production in 1958 to nearly 10 percent in 1967. If exploration, technologies of recovery, and demands advance at expected rates, it is projected that 20 percent of total domestic production in 1980 -- about one billion barrels -- may come from the offshore marine region.

TABLE IV.4.7

Crude Oil Production From The Continental Shelf*

(million barrels)

Location				Total on Shelf	Percent of total production terrestrial and marine
Year	Calif.	La.	Alaska (Cook Inlet)		
1948	14.4	---	--	14.4	0.72
1953	14.8	3.0	--	17.8	0.75
1956	16.5	11.0	--	27.5	1.05
1958	15.8	55.1	--	70.9	2.90
1960	15.2	84.2	0.6	100.0	3.92
1962	17.8	126.9	10.3	145.0	5.45
1964	20.9	163.3	11.1	195.3	7.00
1965	n.a.	197.3	11.1	208.4	7.25
1966	n.a.	243.1	14.4	257.5	8.50
1967	n.a.	291.3	29.3	320.6	9.85

Source: National Council on Marine Resources and Engineering Development, "The Economic Potential of the Mineral and Botanical Resources of the U.S. Continental Shelf and Slope", Report By Economic Associates, Inc., p. 226, 1968.

*It should be noted that totals from Texas are not included in this summary. It is thus a conservative picture of offshore oil production.

Nearly one-quarter of present U.S. reserves are found on the continental shelf. Those reserves found under water depths of 200 feet or less are of particular importance to the estuarine zone; major areas identified as having significant crude oil deposits in near-shore water are listed in Table IV.4.8.

Sulphur mining is another major estuarine activity. Presently, most of the sub-surface extraction is concentrated in three mines, two located on the Continental Shelf several miles off the Louisiana coast, and the third in a coastal bay off the same State. By 1970, these three mines are projected to supply about 2.5 million tons of Frasch sulphur, or about one-fourth of total projected domestic demand.

Significant expansion of this industry in the estuarine zone seems unlikely in the near future, since there are large and economically competitive land-based sulphur sources in western Texas, as well as competition from gypsum byproducts and from probable byproduct recovery under new air pollution restrictions.

The mining of sand and gravel from the estuary floor does not compare in economic importance to the extraction and processing of petroleum and sulphur. The present value of sand and gravel produced in coastal bays and estuaries is estimated to be between 18 and 30 million dollars a year. Marine shell deposits, particularly oyster shell, have been harvested for years, mainly in the Gulf of Mexico and San Francisco Bay. Production of shell was estimated to be about 21 million tons in

TABLE IV.4.8

U. S. Areas With Significant Crude Oil Deposits

Region	Estimated Ultimate Reserves of Offshore Crude Oil (billion barrels)
Atlantic Seaboard (excluding Florida)	1.0
Florida, Northern Gulf Coast	3.2
Mississippi and Alabama	2.9
Louisiana	17.9
Texas	7.0
Southern California	1.3
Alaska, Pacific Coast, and Gulf of Alaska	24.0
TOTAL	57.0

Source: The Economic Potential of the Mineral and Botanical Resources of the U.S. Continental Shelf and Slope, op. cit. p. 221.

These figures reinforce those already cited and identify the Gulf of Mexico biophysical region as the probable future focus of continental United States petroleum recovery and secondary processing growth. Alaska, perhaps including the Bering Sea and Arctic margins, is also certain to be an area of increasing exploration, recovery, and refining.

1966, with a value of approximately 33 million dollars.

Yet, the mining of sand, gravel, and shell has a significant impact on estuarine conditions wherever it is practiced. Unlike petroleum, the mining of these aggregates is not the spur for industrial and population expansion. The reverse is true. Demand for coastal and estuarine deposits of aggregates is the direct result of metropolitan growth and related urban demands for cheap construction material in the form of concrete and other building products.

Since suitable construction aggregates are found nearly universally on the Atlantic, Gulf, and Pacific coasts, and transportation of these materials often makes up one-half or more of the costs to the consumer, present and future growth of this industry in the coastal-estuary zone will be dependent on increasing urban developments, and the availability of competing deposits on the land surface. Thus, projections of growth of coastal-estuarine extraction of aggregates are difficult due to the fact that local demand and supply conditions are now and will continue to be the major determining factor in decisions to exploit marine aggregate resources.

Sources of aggregate extracted from supplies in coastal rivers and estuaries already provide the principal source of sand and gravel for such metropolitan areas as New York, Philadelphia, Baltimore, Washington, D.C., Norfolk, Mobile, and New Orleans. Oyster shell is a major source of cement and associated lime requirements in Galveston Bay, texas. Significant quantities are also mined in the San Francisco

Bay. It seems reasonable to conclude that as urban areas continue to grow through suburban expansion, as land values rise and as zoning restrictions are tightened, that the demand for estuary reserves of sand, gravel, and shell will grow. Offshore dredging on a massive scale is presently precluded due to the high cost of building suitable dredges, technological difficulties of deep water recovery, and competing resources on land and the estuaries.

Salt is an obvious yet relatively insignificant product extracted from estuarine water. Only three of over one hundred salt producing operations are located in estuarine areas. Their total production in 1967, valued at $17 million, was about 7 percent of the total U.S. production. Such activity in estuarine areas is bound to decline as pressure is exerted by more competitive uses of estuarine land.

Current interest in exploiting phosphorite and manganese nodules and contiguous deposits of nickel, cobalt, and copper is limited by available technology. Gold and platinum metals exist in submerged beach and placer deposits off Alaska, California, and Oregon but it is unlikely that maining will be undertaken for them in the near future. Diamonds, gold, and zircon have also been identified in the estuarine sands of various States, but extraction appears unlikely.

Magnesium metal, magnesium oxide, and bromine are all extracted from seawater and plants are presently located mainly in the estuarine zones of Texas and California. Production is adequate for projected demand

and little expansion is anticipated, at least within the estuarine area. Relatively little modification of the estuarine environment results from these activities.

In review, the future of mining in the estuarine zone and near coastal waters will center on two categories of minerals that may give rise to serious and increasing pressures on that environment: petroleum, gas and sulphur, and sand, gravel, and shell. Improved management of estuarine resources must take these primary and the associated secondary and marginal activities into account in any rational scheme to balance and optimize the values of the Nation's coastal resources.

OUTDOOR RECREATION

Historical Trends

Outdoor recreation awareness has existed since the establishment of the first communities in the United States with their typical commons and public parks. Parks and their value to an urban society were re-emphasized by the great city planning movement of the latter decades of the 19th century. This revival was accompanied by an awareness on the part of urban scholars that natural resources were not inexhaustible and should receive a measure of protection. The effect, of course, was the establishment of the national park and national forest systems largely centered in the western States and areas of very light population. The advent of the state park movement in the 1920's was augmented by a variety of national initiatives during the 1930's which tended to establish some balance in the distribution of land areas managed by

public agencies for a variety of public purposes including outdoor recreation. The objectives werelargely resource-protection oriented and the facility development which took place during the 1930's was directed far more at providing employment than meeting, in a planned fashion, identified outdoor recreation needs.

The years of World War II and a suddenly released affluence during the decade following the cessation of hostilities combined to produce an enormous awareness on the part of a rapidly changing society that the opportunities afforded by the public stock of resource areas was inadequate to meet their needs. A variety of landmark investigations into the status of outdoor recreation were undertaken and published during that decade. Principal among them were: intensive studies of the shorelines of the United States by the National Park Service, and a preparation of Operations Outdoors Program by the United States Forest Service. These investigations sulminated in the establishment of a California Outdoor Recreation Study Committee and the National Outdoor Recreation Resources Review Commission.

Measures of Demand

Both these studies for the first time demonstrated the basic causal factors in outdoor recreation demand. In effect, they found that adequate planning for outdoor recreation required larger concerns than the biophysical environment; that the economic environment -- expressing the preference of society for goods and services -- and the institutional environment -- decisions about the focus and

characteristics of agencies charged with the protection of resources and the provision of outdoor recreation facilities -- were equally important.

The principal causal factors noted and documented by the Outdoor Recreation Resources Review Commission Reports were:

(1) Growth in total population;

(2) Growth in leisure time;

(3) Increased mobility of the total population including transportation;

(4) Changing population characteristics of the total population; and

(5) Concentration of population in urban or metropolitan centers.

It was concluded that as the levels of these factors rose, the growth of outdoor recreation demand for specific activities or opportunities would accelerate faster than the net increase in total population. Sections 1 and 2 showed that these principal factors in the growth of outdoor recreation demand will exhibit sustained growth both nationally and within the estuarine zone. Therefore, although no specific quantification is presently available to project actual recreational demands on and uses of the Nation's estuarine resources, they will certainly increase at substantial rates in the future. It is uncertain at whether the supply of recreation resources will in fact be sufficient to meet this large, if unquantified demand. Continued degradation and

restriction of recreation resources, particularly those in the estuarine zone, may well mean that some of the potential demand will be cancelled by overcrowded, unattractive areas already much in evidence.

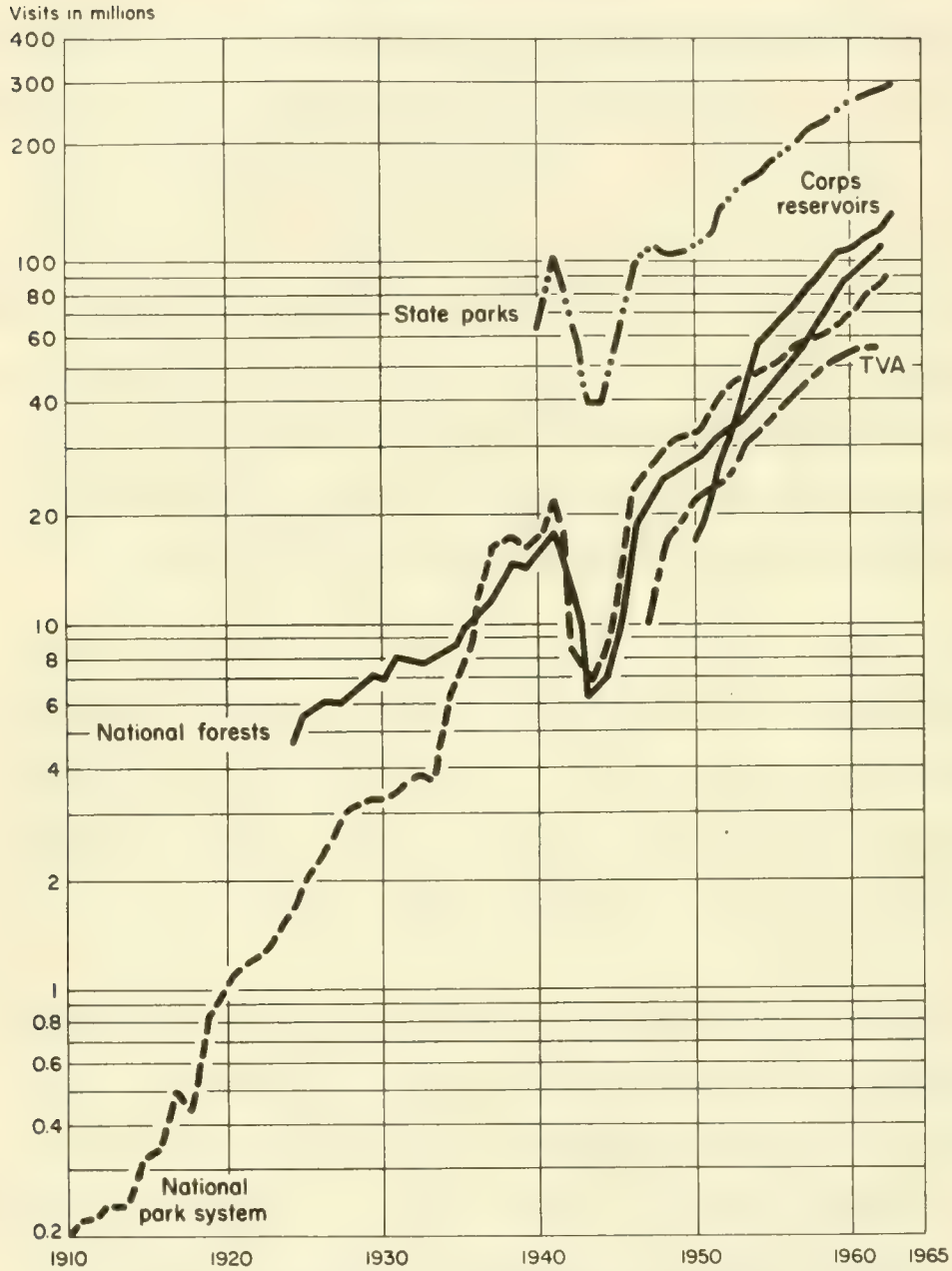
Although specific estuarine projections are not available, it has been generally concluded by experts in the field that one indicator -- attendance in public parks -- has risen at about 10 percent annually for many years. Thsi is a rate more than five times the rate of the "population explosion" noted in Section 1. There are indications that this comparative rate of growth for the outdoor recreation experience in public park areas must level off, but the immediate future would seem to maintain the trend toward more overcrowding and use and the modifying pressures these entail as Figure IV.4.15 indicates.

Recreation demands are expressions of desire for certain activities and thus are difficult to translate into requirements for particular quantities of bay shoreline, acres of marsh, and so on. Thus the magnitude of future demands and the consequent requirements for associated estuarine resources is extremely difficult to pinpoint.

Perhaps the most common indicator of recreation growth is expressed by "user days" of some particular activity. An example of this is provided by the national trends and projections developed by the Bureau of Outdoor Recreation. Figure IV.4.16 indicates the projections for five outdoor recreation activities that occur in the estuarine

Figure IV.4.15

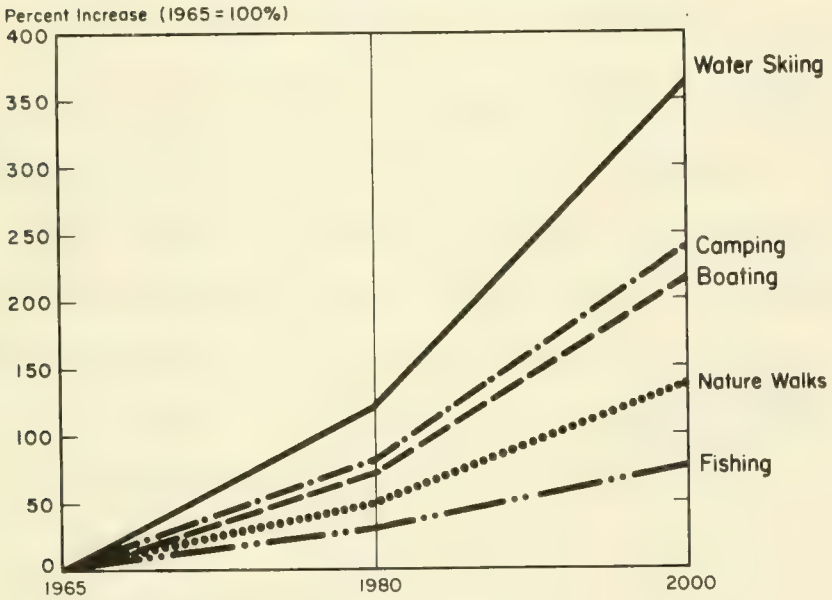
ATTENDANCE AT MAJOR TYPES OF OUTDOOR RECREATION AREAS



Source: Marion Clawson and Jack L. Kultsch, Economics of Outdoor Recreation (Baltimore: John Hopkins Press, 1966), P. 44.

Figure IV.4.16

PERCENT INCREASES IN SELECTED OUTDOOR RECREATION AREAS



Source: Bureau of Outdoor Recreation

environment although, obviously, they can be accommodated in other areas as well. Numerous other inventories indicate similar exponential projections of recreation activity in coming decades. Of particular note here are the inescapable conflicts generated among recreation users themselves, and on the finite land and water resources of the Nation. For example, the tremendous rise in water skiing and high speed motor boating directly conflicts with the more quiet pursuit of sport fishing which is increasing simultaneously.

It is necessary to distinguish between actual demands and potential demands. The actual demands for certain recreation activities such as hunting, sight-seeing, and boating can be, in a general way, obtained from areas in which these activities are well-established and monitored. However, in many areas the potential for certain recreational activities is much higher than indicated by present use. For example, the Delaware Estuary Comprehensive Study (1966) estimated that the upper Delaware estuary alone had a capacity of over 8,000,000 activity days for boating, while only 1,800,000 activity days are currently being used, which amounts to a utilization of the boating potential of only 23 percent. Similarly, only 8 percent of the sport fishing capacity in the upper Delaware estuary appeared to be realized. Even though the definition of "capacity" used in this and similar studies is open to serious question, future demands will place great pressures even on those areas which appear to be "under-utilized" today.

On the other hand, it is known that the hunting opportunities in State and Federal reserves are not as good as they are on carefully managed private areas. This is due to the special characteristics of waterfowl, their sensitivity to overhunting, and the necessary latitudes of hunting pressures on publicly managed lands. It appears unlikely, however, that privately owned and managed lands, particularly those fronting on the estuaries, can maintain sufficient opportunities for future outdoor recreation let alone expand them.

This points out that while there may be ample present opportunities for some recreation activities in certain areas, on others the system and use demands impose severe limitations. It must be one of the prime concerns of the management of the estuarine resources that while they will be used increasingly for all purposes, the resource base that satisfies recreation demands must be retained. Destruction of the resource base would constitute the final absurdity of destroying the objects of increasing demand for the satisfactions of this environment.

User Groups

The recreation pressures on estuarine resources are generated by three basic user groups. They are:

(1) Periodic: Those who either reside in the estuarine zone or within short travel distance from the estuarine zone and who travel from their place of residence to the estuary resources, participate in outdoor recreation activities, and return to their place of residence within a single day.

(2) Seasonal: Seasonal recreation users are those who maintain residences at another place but who spend more than one day at a time in the estuarine zone. These users may range from those who spend a single weekend to those who spend one or two weeks or several months in some form of residence, i.e., campground, hotel-motel, or cottage in the estuarine zone.

(3) Permanent: Those who maintain permanent recreation residences in the estuarine zone.

The demands for, and use of, the recreation resources in the estuarine zone by all three user groups will increase substantially in the future. Periodic users already overburden recreation facilities near metropolitan areas as anyone who attempts to reach near shore areas on weekends is well aware. With the growth of megalopoli from Maine to Virginia, both coasts of Florida, northern Texas and California in the near future, pressures from day-use participants is certain to rise.

In addition, both the periodic and seasonal user groups concentrate the bulk of their pressures on the estuarine and coastal environment in the short summer months span. Thus, the greatest use is made of the shoreline and water in the period of maximum vegetal growth, and often the time when supplies of fresh water for all purposes such as drinking, carrying municipal wastes, etc., are least available. Instructive in this regard is the growth of resort communities, such as Ocean City, Md., from sleepy towns of 25,000 persons in April, to

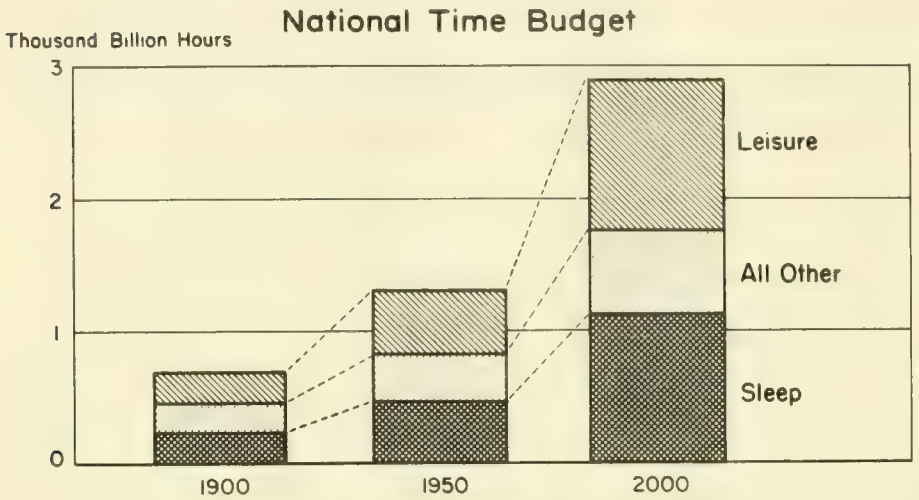
"cities" of 350,000 on weekends in the summer months.

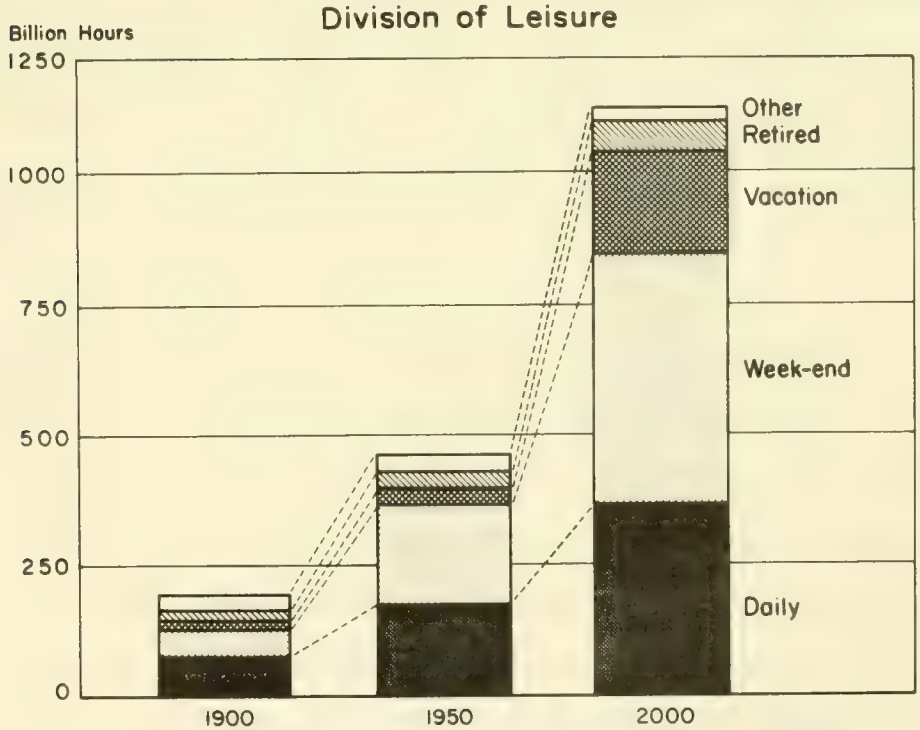
Perhaps the greatest recent change in user group pressure results from the tremendous growth of permanent residences constructed in coastal and estuarine locations. Recreation amenities provided by these areas is a prime factor in this trend. Although growth figures are not uniformly available, the growth of permanent and "second" homes appears to be general throughout the Nation, particualrly in outlying "suburbs" tied to metropolitan job centers by expanding transportation networks. This growth of permanent users of the estuarine zone is further increased by the phenomenal expansion of retirement communities in such areas as Florida, Texas, and California.

Figure IV.4.17 summarizes the projections of leisure time which contribute heavily to the pressures discussed above.

Figure IV.4.17

NATIONAL TIME BUDGET AND TIME DIVISION OF LEISURE, 1900, 1950, AND 2000





Source: Marion Clawson, How Much Leisure: Now and in the Future, (Washington, D.C.: Resources for the Future, Inc., 1964), P. 11.

SECTION 4. FUTURE WASTE DISCHARGE IMPACTS

The amounts and impact of wastes generated by man's activities are a function of population growth, urbanization, industrial and commercial development, changing technologies, and consumption of goods and services -- even those associated with leisure time activities. The following discussion defines trends and the probable future course of events related to waste discharge affecting the estuarine zone. However, in most cases, only an indication of the magnitude of the problem can be set out here due to the lack of comparable long-term data, the complexity of the waste discharge assimilation process and the unknown quantity and composition of future waste discharges.

The emphasis in the following discussion is on those trends in waste discharge that most directly affect water quality, although it must be recognized that the problems associated with wastes affect the total environment, and extend well beyond the defined area of the estuarine zone, both landward and seaward.

LIQUID WASTES

Fresh Water Inflows

Many of the sources that determine estuarine water quality are and will be external to the estuarine zone. The quantity, as

well as quality, of fresh water inflows to the estuaries is largely determined by upstream water use. Water diversion for irrigation, impoundment for flood control, and a host of other uses tend to cut the natural stream flow necessary to the successful assimilation and diffusion of both natural and man-made wastes. An example of upstream diversion of water is provided by the Texas Water Plan, which is projected to alter streamflows radically into such productive estuaries as Galveston Bay and those situated in the southern Texas coast. Even if a tremendous planned diversion from the Mississippi River for fresh water inflows to the estuaries is completed on a timely basis, these estuarine systems are projected to face overall reduction of fresh water supply and the accompanying stresses both on the natural assimilative capacities of these estuaries and the biotic communities presently existing there.

Pressures for increased upstream diversion and use of fresh water are certain to increase in all biophysical regions, but the relatively arid and high growth Western Gulf and the Southwest Pacific coasts are projected to experience the greatest pressures on present estuarine systems for at least three main reasons:

(1) Much of the upstream water is used to support irrigation with accompanying actual loss of water to the inflow systems by evaporation, transpiration, and absorption, as well as mineralization through leaching.

(2) The amount of rainfall and snow pack is highly variable

and often results in extended periods of flooding and drought in these Regions.

(3) Consumption of water other than for irrigation is bound to increase at a high rate in response to expected population growth considerably above the national average.

It should be noted, however, that these diversion projects may also allow increased control of water inflows that could be beneficial to maintenance of existing estuarine productivity. Furthermore, some proposed projects may merely shift the major portion of existing inflows from one area to another as in the case of the proposed diversion of Delaware River inflow from Delaware Bay, through the Hudson River, to Raritan Bay and New York Harbor.

Municipal Wastes

Municipal waste water disposal is the most frequently cited example of water quality degradation. The major impact of municipal waste water discharge is calculated on the basis of the amount of Biological Oxygen Demand (BOD), bacterial indicator organisms, generally coliforms, and suspended and dissolved solids reaching both fresh and estuarine water. The magnitude of the future extent of the water pollution problem is indicated by the projection that even if secondary treatment were provided for all urban and sewered population in the United States by 1980, the amount of residual wastes reaching the Nation's waters would be about the same as today when

much of this population is not served by secondary treatment facilities. From approximate coefficients developed by the Federal Water Pollution Control Administration for municipal wastes generated by man in areas served by sewers, a rough estimate of the overall yearly municipal sewered waste loads may be computed for the estuarine zone as shown in Table IV.4.9.

Although these figures are approximate, and understate the magnitude of the municipal waste load in the estuarine zone, they indicate the tremendous pressure increasing population itself will place on the water quality of the estuarine zone in the future. It does not take into account the increasing use of high water use appliances such as washing machines, dishwashers, and garbage disposals which will contribute significantly to higher per capita water wastes in the future.

TABLE IV.4.9
Approximate Municipal Wastes Generated Yearly By The Estuarine Zone Population, 1960-1980

	1960	1970	1980	Numerical Increase 1960-1980
Waste water, billion gallons	1,611.7	1,902.3	2,130.7	519 billion gallons
Standard BOD, millions of pounds	2,229.5	2,631.5	2,947.4	718 million pounds
Settleable and Suspended Solids, millions of pounds	2,686.1	3,170.5	3,551.1	865 million pounds

These projections are based on formulae found in the FWPCA publication, The Cost of Clean Water, Vol. II, "Detailed Analysis", (Washington, D.C.: U.S. Government Printing Office, 1968), p.68

These figures are reasonable statements of pressures from urban populations, but the exterior suburban and rural populations presently not served by sewers will undoubtedly contribute further significant liquid-bearing wastes to the estuaries. For example, beach front and estuarine communities, particularly resort-oriented developments, have traditionally and continue to depend in large degree on septic tank disposal of municipal wastes. Problems of waste seepage from septic treatment have been noted in such places as the north and south shores of Long Island, Florida resort and retirement communities, and the Delaware-Maryland-Virginia shoreline. Furthermore, many coastal communities were originally sewered with primary treatment facilities. These facilities, often discharging directly into shallow back bays, are no longer adequate to meet increased development, density pressures and the longer duration of stays caused by burgeoning "second home" markets. The communities, limited to residential tax bases, are hard-pressed to finance facilities adequate to handle peak loads reached for relatively short periods in the critical summer months.

A final indicator of the magnitude of the municipal waste problem is provided by Table IV.4.10. The marine coastal states are projected to require an outlay of five and one-half billion dollars between 1969 and 1973 to adequately treat municipal wastes during that period. This represents 63 percent of the national total of 8.693 billion projected for 1969 through 1973. The estuarine portions of the marine states (basically the coastal counties) are estimated to require 60 percent of the Marine states' total outlay, or something over two and

TABLE IV.4.10

Capital Outlays Needed to Obtain Adequate Municipal Waste Treatment for Urban Populations in Marine Coastal States and Estimates for Estuarine Associated Portions of Those States, 1969-1973

State	Entire State (Millions of Dollars)	Estuarine Portions of States (Millions of Dollars)
Alabama	137.0	15.2
Alaska	14.5	Unk.
California	732.2	574.0
Connecticut	188.3	118.0
Delaware	31.5	31.5
District of Columbia	23.0	23.0
Florida	369.6	286.3
Georgia	223.1	15.1
Hawaii	40.1	40.1
Louisiana	195.0	91.1
Maine	47.0	21.3
Maryland	136.1	124.4
Massachusetts	200.0	149.0
Mississippi	57.0	4.9
New Hampshire	35.0	9.2
New Jersey	561.1	507.7
New York	1070.1	682.0
North Carolina	101.5	11.4
Oregon	145.3	92.1
Pennsylvania	331.6	105.2
Rhode Island	41.5	41.5
South Carolina	100.0	19.6
Texas	342.5	88.1
Virginia	206.6	114.1
Washington	173.3	121.0
Totals (Millions of $)	5,503.0	3,285.8 (60%)

Source: Computed from Table 1-3A in The Cost of Clean Water, op.cit., p. 13.

a quarter billion dollars during the same period.

As one might expect, the heavily-populated estuarine-associated States such as California, New York, New Jersey, and Florida will require bulk of expenditures in the near future (nearly two-thirds of the total). Similarly, the estuarine portions of the Marine states located in the Middle Atlantic biophysical region (New York to Delaware) will account for nearly 44 percent of the national total for these areas. These and other urban-dominated areas will require the fullest possible resources, technology and planning of private, local, state, and Federal establishment if estuarine water quality is to be maintained, and perhaps enhanced.

Industrial Wastes

Although municipal wastes are shown to be a major and projected source of pollution, both nationally, and associated with the estuarine zone, manufacturing is the principal source of controllable waterborne wastes.

In terms of the generally quoted measurements of strength and volume, the FWPCA estimates that manufacturing establishments are responsible for about three times as great a loading as that caused by the Nation's population. Moreover, the volume of industrial production, which gives rise to industrial wastes, is increasing at about 4.5 percent a year, or three times as fast as the population growth rate.

Approximately 85 percent of the 14.2 trillion gallons of water used by manufacturing plants in 1964 was accounted for by four major industry groups. Namely: Primary Metal Industries, Chemical and Allied Products, Paper and Allied Products, and Petroleum and Allied Products. Most of the growth in manufacturing water demands between 1954 and 1964 may be attributed to these four industry groups. This may be expected to continue in at least the near future. Blast furnaces and steel mills alone accounted for 27 percent of the total; industrial chemicals for about 21 percent of the total. Relatively large industry units account for nearly all measured industrial uses; 3 percent of the firms inventoried by the Census of Manufactures made up 97 percent of the total industrial water used for the Nation.

Estuarine economic areas identified as having significant concentrations of high water use industries are:

(1) Chemicals and allied products: New York-Northeast New Jersey, Philadelphia-New Jersey-Delaware Coast and the Texas North Gulf Coast.

(2) Petroleum refining: Philadelphia-New Jersey-Delaware Coast, Louisiana Coast, Texas North Gulf Coast and Texas South Gulf Coast, and California Coast.

(3) Paper and allied products: Marine Coast, South Carolina Coast, Georgia-Eastern Florida Coast, Central Florida Gulf Coast, Mississippi-Alabama-West Florida Coast, Oregon Coast and Washington Coast.

All of these industries have high growth potential and may be expected to intensify their activities in the future.

Other high water use industries of importance to individual estuarine areas are:

(1) Textiles: Massachusetts-Rhode Island Coast, New York-Northeast New Jersey Coast, North Carolina Coast, and Mississippi-Alabama-West Florida Coast.

(2) Primary metals: Connecticut Coast, Maryland-Virginia Coast and the Texas North and South Gulf Coasts.

(3) Food and kindred products: Philadelphia-New Jersey-Delaware Coast, North Carolina Coast, Southern Florida Gulf Coast, Central Florida Gulf Coast, Louisiana Coast, the California Coasts and the Oregon and Washington Coasts.

Thermal Wastes

Although heated effluents may come from a variety of sources, electric power generation is estimated to produce 81 per cent of the total heat discharged to the Nation's waters. Demand and production of electric power in this country has doubled every ten years during this century, with most of the increase coming through use of thermal-generating methods. Power requirements of electrical systems in 1980 will be three times what they were in 1963.

As Table IV.4.11 indicates, overall expansion of electric generating capacity for the Nation will average about 6 per cent annually during the period 1959-1980. Areas of particularly rapid growth include Florida, parts of the Gulf coast, Texas, and Puerto Rico.

Modern plants being installed presently, and in the near future, will be larger in unit size, thereby increasing plant efficiency, but concentrating heat effects to a significant degree. Hydroelectric power generation, with the exception of the Pacific Northwest, is projected to decline in importance. Fossil and particularly nuclear power generation will expand tremendously to meet expected demands. It is estimated, for example, that by 1975 about half of the generation capacity will be nuclear fueled.

The growth of nuclear power is significant, not only because of the large unit size (800 megawatts or larger), but because they must presently operate at lower, and therefore, less efficient temperatures. In sum, it will take more heat to generate a given amount of electrical energy in the future, and more of that heat will have to be dissipated somehow into cooling waters. Figure IV.4.18 gives an indication of the growth of new nuclear generating plants to 1973.

Although the actual future number of fossil and nuclear plants located on the coasts and estuaries of the United States is unknown, an indication of future thermal alteration potential is provided

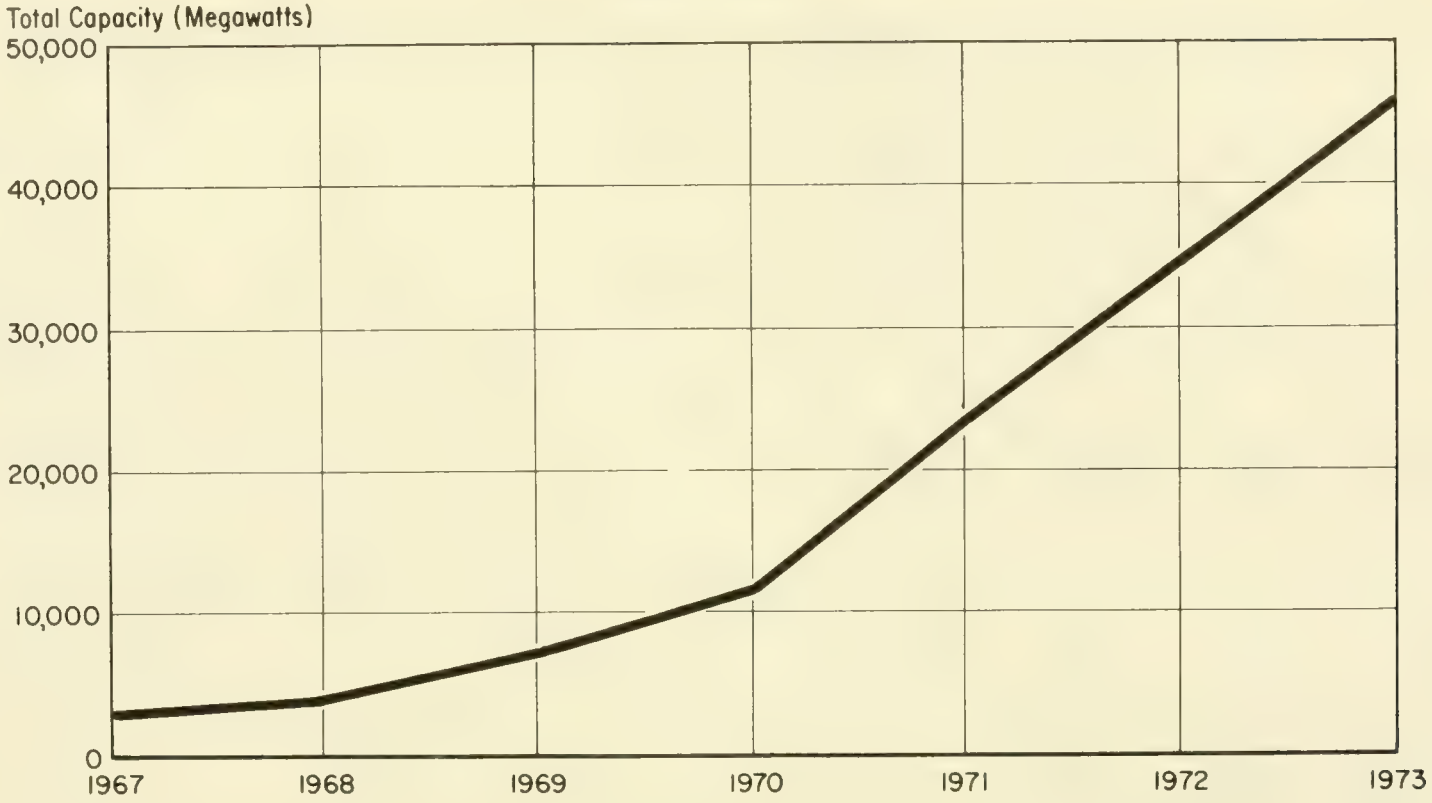
TABLE IV.4.11
Electrical Generating Capacity in the United States
Areas Associated with the Estuarine Zone, 1959-1980

Power Supply Area	Electrical Megawatts: Total Installed at End of 1959	Additions Installed in 1960 thru 1966	Additions Expected for 1967 thru 1973	Additions Forecast for 1974 thru 1980	Average Percent Increase per Year
New England (PSA 1 & 2)	6,700	2,300	5,500	6,900	5.7
New York (PSA 3 & 4)	11,600	5,800	6,100	9,900	5.2
New Jersey; Delaware; most of Pennsylvania & Maryland; District of Columbia (PSA 5 & 6)	12,800	6,000	11,200	15,900	6.3
Most of Virginia; North Carolina; South Carolina (PSA 18 & 21)	8,400	5,300	7,900	13,000	7.0
Most of Florida (PSA 24)	3,300	4,300	6,700	15,400	11.1
Northwestern Florida; Georgia; most of Alamama & Mississippi; Louisiana; Western Arkansas (PSA 22, 23, & part of 25, 33, & 35)	8,300	5,900	10,900	18,600	8.2
Oklahoma; Texas; New Mexico (PSA 36-39, & rest of 33 & 35)	11,700	8,100	15,600	26,100	8.2
Washington; rest of Idaho & Oregon (PSA 42-45)	9,300	4,500	9,300	13,300	6.7
California (rest of PSA 46-48)	12,800	8,500	9,200	16,500	6.4
Alaska	200	-----	------	------	----
Hawaii	500	-----	200	200	2.8
Puerto Rico	400	200	600	900	8.2
Total for United States	158,000	75,000	139,000	207,000	6.3

Source: United States Atomic Energy Commission, Forecast of Growth of Nuclear Power.

Figure IV.4.18

TOTAL NUCLEAR-FUELED GENERATING CAPACITY OPERATIONAL IN YEARS 1967-1973



by future operation of the following plants affecting coastal waters:

TABLE IV.4.12
Expanded or Projected Power Plants Affecting Estuarine Waters

Project	Megawatts	First Electricity
Maine Yankee Atomic Power Plant Lincoln, Maine	790	1972-73
Pilgrim Station Plymouth, Massachusetts	625	1971
Connecticut Yankee Atomic Power Plant Haddam Neck, Connecticut	462	1967
Indian Point Station - Unit 1 Buchanan, New York	265	1962
Indian Point Station - Unit 2 Buchanan, New York	873	1970
Oyster Creek Nuclear Power Plant Oyster Creek, New Jersey	515	1969
Oyster Creek Nuclear Power Unit #2 Oyster Creek, New Jersey	815	1972
Peach Bottom Atomic Power Station Unit #1 Philadelphia, Pennsylvania	40	1967
Peach Bottom Atomic Power Station Unit #2 Philadelphia, Pennsylvania	1065	1971
Peach Bottom Atomic Power Station Unit #3 Philadelphia, Pennsylvania	1065	1973
Surry Power Station Unit #1 Surry County, Virginia	783	1971
Calvert Cliffs Nuclear Power Plants Unit #1 Maryland	800	1973
Calvert Cliffs Nuclear Power Plants Unit #2 Maryland	800	1973
Brunswick Steam Electric Plant Unit #1 Brunswick County, North Carolina	821	1976
Brunswick Steam Electric Plant Unit #2 Brunswick County, North Carolina	821	
Crystal River Plant Unit #3 Crystal River, Florida	825	1972
Humbolt Bay Power Plant San Onofre, California	430	1967
Malibu Nuclear Plant Unit #1 California	462	1973
Rancho Seco Nuclear Generating Station California	800	1973
Diablo Canyon Nuclear Power Plant Unit #1 San Luis Obispo, California	1060	1971
Diablo Canyon Nuclear Power Plant San Luis Obispo, California	1070	1974

SOLID WASTES

Solid wastes, particularly those associated with urban areas and concentrations of industry, must be recognized as major hazards to the maintenance of a desirable estuarine environment. The problem of disposal of solid wastes becomes particularly acute as available land surrounding central cities is built up. Traditionally, wetlands have been considered convenient sites for the disposal of all types of unwanted material, from demolition wastes to tricycles. It is estimated that the amount of land necessary to store and/or process solid wastes for ultimate disposal will nearly double from 1966 to 1976.

A recent report conducted for the Regional Plan Association studied the New York Metropolitan area generation and handling of wastes. The study found that in 1965 the residential solid wastes generated per capita per year averaged from about a half a ton to nearly two-thirds of a ton. Thus, nearly eleven million tons of residential solid wastes were generated in the New York Metropolitan area in 1965. By the year 2000, it is estimated that residential solid wastes may triple.

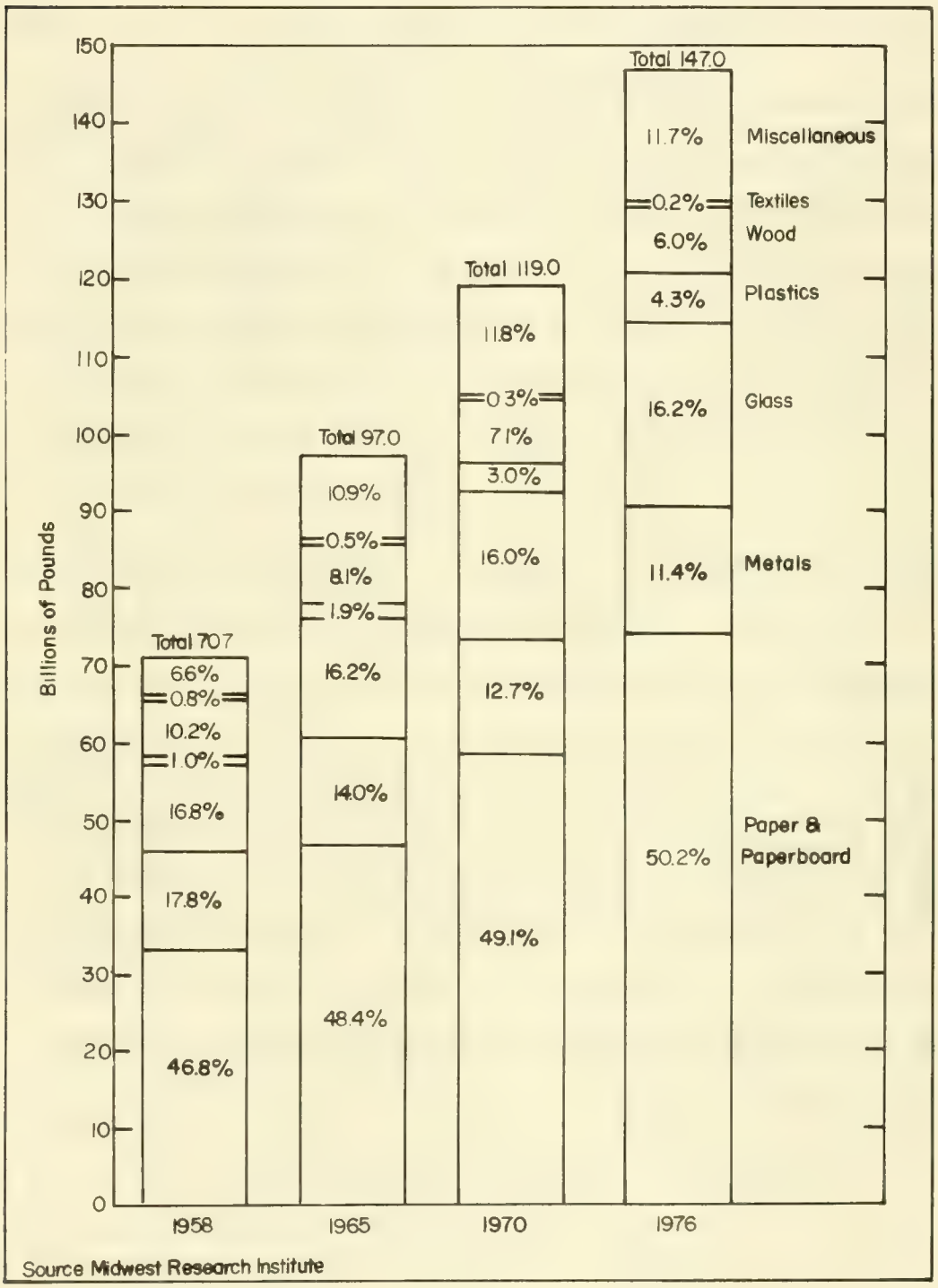
Solid waste by business was also found to be significant. An estimated six and a half million tons were generated in the study area in 1965 and the high projection for 2000 indicates a solid waste load for that year of over 22 million tons.

Within comparative limits, the New York example is being repeated throughout the Nation, and particularly in metropolitan areas associated with the estuaries.

Factors affecting the extent of the solid waste disposal problem, including internal processing techniques and external changes arising from social, economic, marketing and consumption trends, indicate that solid wastes will expand at a rate substantially exceeding population growth in the foreseeable future and radically change both in volume and character. This projected situation is graphically highlighted by Figure IV.4.19. It should be noted that the gross amounts of non-degradable packaging materials such as plastics will also greatly expand, and the trend toward disposable containers will also contribute to the solid waste that must be accommodated by the environment.

This brief review of the future of the estuarine zone as a receptacle for man-caused wastes leads to the conclusion that the continuation of current trends will ultimately bring about the destruction of much of the estuarine system as we know it. A great commitment of money, manpower, and technology will clearly be required to alleviate the ill effects of current practices and to prevent damages in the future.

FIGURE IV.4.19 CONSUMPTION OF PACKAGING MATERIALS BY WEIGHT 1958-1976 (BILLIONS OF POUNDS)



SUMMARY

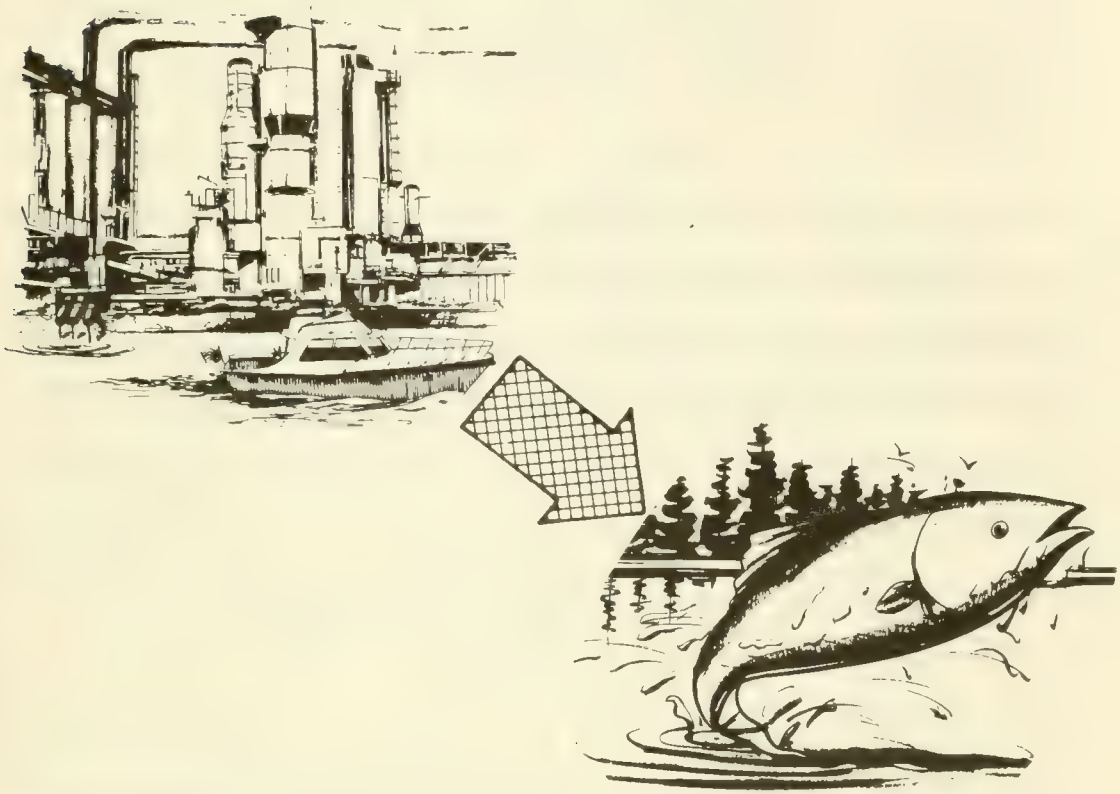
The anticipated continuing increase in population and industrial development in the estuarine zone will increase the strong pressures presently existing on the estuarine biophysical environment. The economic pressures will lead as coastal resources are exploited in more ways and more intensively, and as commercial exploitation of the deep ocean makes itself felt through use of the estuarine zone as a staging area.

As the economic pressures increase, more and more estuarine areas will be preempted for commercial purposes, to the detriment of the intrinsic social value of the estuarine zone. The anticipated great increase in recreational need will tend to follow economic development; therefore, recreational use may very well be relegated to small areas useless for other purposes unless effective overall management of the entire resource can be established and maintained.

The great projected increases in waste discharges from all sources may do far more than usurp other uses -- these wastes can destroy part of the environment itself and thereby damage the very ecosystem of which man is an integral part and from which his sustenance comes.

Chapter 5

POLLUTION IN THE ESTUARINE ZONE



Man has always used the biophysical environment as he needed it for survival and thrown back into it his waste products and anything else he did not need. As long as civilization was limited to small towns and villages the impact of such treatment on the environment was not noticeable and apparently insignificant. With the development of a civilization based on a complex socioeconomic environment, however, his impact on the estuarine environment has increased until now the most accurate term to express the relationship of man to the biophysical environment is "pollution".

"Pollution" is the degradation of the biophysical environment by man's activities; it is no longer limited to the discharge of sewage and industrial wastes, but now includes direct or indirect damage to the environment by physical, chemical, or biological modification.

This chapter shows the relationship between man's presence in and use of the estuarine environment and its degradation. The kinds of materials and types of changes that tend to degrade the environment are the first topics of discussion, then the relationship of pollutional conditions to the various socioeconomic activities are described. The chapter concludes with a description of the impact of the socioeconomic environment on the biophysical environment and specific examples of pollutional effects.

SECTION 1. MATERIALS AND CONDITIONS THAT DEGRADE THE ENVIRONMENT

Environmental degradation is the result of often minute changes in water quality, water circulation, or other conditions which are part of the biophysical estuarine environment. Brightly colored or otherwise visible waste materials (Figure IV.5.1) have obvious pollutional implications, but by far the deadliest pollutants are those that are invisible and often unsuspected until the damage is done. These pollutants can be found only by the most delicate and sensitive tests; even then, the presence of some highly dangerous materials or conditions can only be inferred from indirect evidence.

DECOMPOSABLE ORGANIC MATERIALS

One major constituent of municipal and many industrial wastes is decomposable organic material. Such materials consist primarily of carbohydrates from plants and paper, proteins from animal matter, and miscellaneous fats and oils (Figure IV.5.2). The decomposable organics are not necessarily detrimental by themselves, but they exert a secondary effect by reducing dissolved oxygen in the water. This oxygen resource depletion results from the biochemical reactions involved in microbial utilization of organics for food.

The biochemical oxygen demand (BOD) is the standard test for this component. It is an index of the availability of organic matter for biological food and the amount of oxygen utilized by organisms in

the metabolism of this food. BOD is generally expressed as (milligrams per liter) mg/l of 5-day BOD at 68°F. while natural waters have values around 1, untreated domestic sewage may average around 300.

The flow of oxygen resources in an estuary is analogous to the flow of money in a bank if the estuarine system is viewed as a dissolved oxygen bank. There is a certain amount of oxygen in the system just as there are certain assets in a bank; the oxygen is invested in supporting and renewing the biota, while the bank assets are invested to earn money. There is a constant flow of oxygen into and out of the estuarine system, both to and from the atmosphere and the ocean. In the bank there is a cash flow to and from the depositors. Large waste discharges may exert an abnormal demand on the oxygen resources such as an embezzler exerts on the cash resources of a bank. If enough dissolved oxygen is utilized in stabilizing wastes the system goes bankrupt.

The amount of organic wastes that can be assimilated in the estuarine system without stressing the biota is dependent on the oxygen balance or the flow of oxygen in the system. The rate of oxygen renewal is dependent on the tidal driving force causing new oceanic water to flood into the system, the fresh water inflow, the wind, the surface area and the amount of turbulence generated by the fresh-oceanic water mixing. The more turbulent the system the greater opportunity for atmospheric exchange with the attendant ability to assimilate

more wastes (Figure IV.5.3). Severely depressed dissolved oxygen levels, which result from an excess of oxygen-consuming organic wastes, affect many categories of beneficial uses. With aquatic habitat damage, pollution-tolerant plants and animals replace the more sensitive types. Desirable game and food fish may be completely eliminated; areas of low dissolved oxygen may block the passage of anadromous fish, thereby affecting the reproduction cycle. If oxygen is totally depleted, noxious odors may develop, completely eliminating such uses as boating, swimming, and esthetic appreciation.

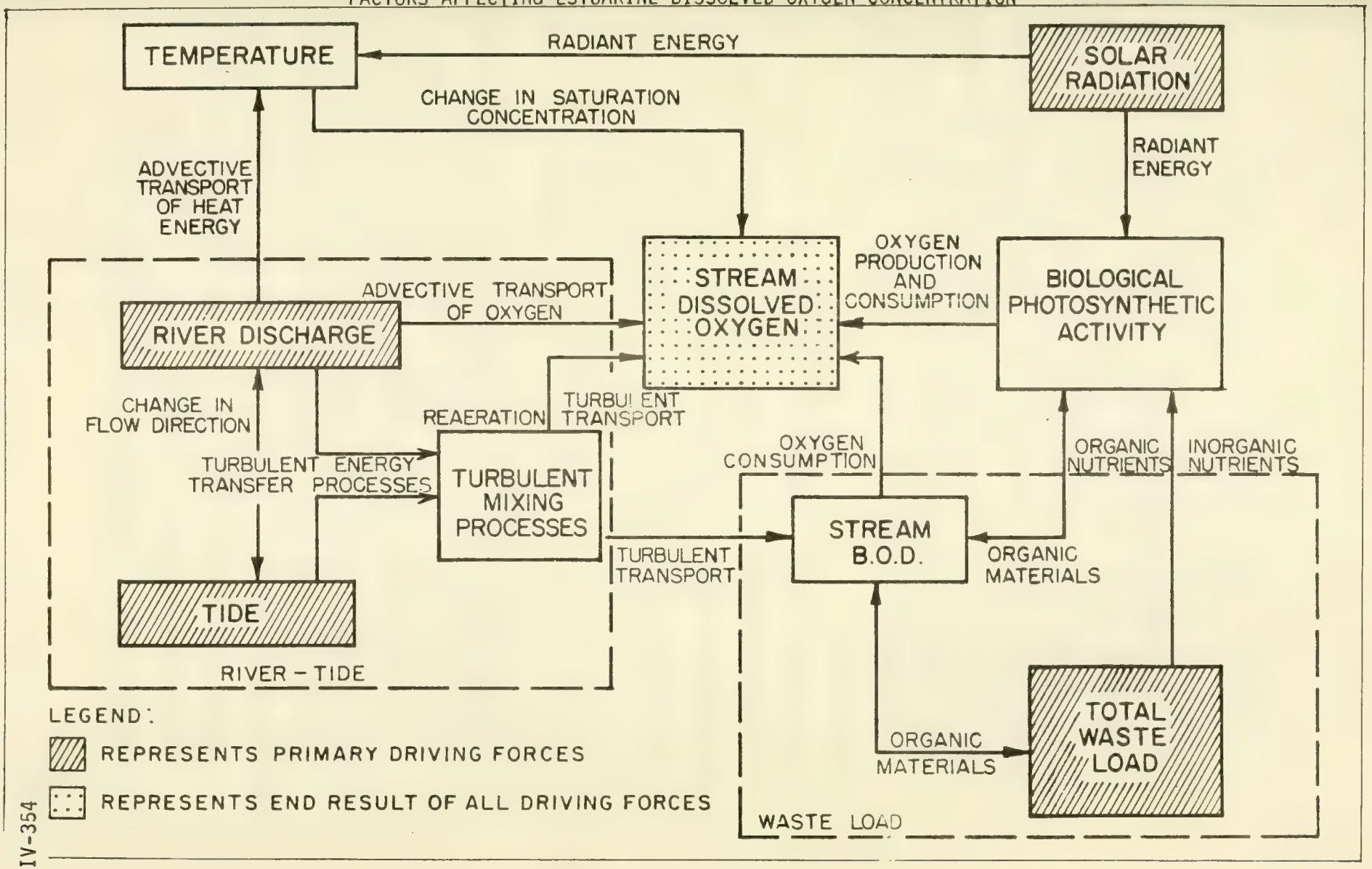
The level of dissolved oxygen in the water is one direct index of the healthiness of the system. High levels generally indicate a healthy system which will support a diverse biota and multiple use. The lower the concentration of dissolved oxygen becomes, the sicker the system is, and the less desirable it is for habitat or use.

FLESH-TAINTING SUBSTANCES

Another class of materials, primarily organic, which can have considerable impact on the estuarine ecosystem, are the flesh-tainting substances. Generally these materials are contained in industrial waste effluents and they result in offensive tastes, odors and colors of fish and shellfish. The most common culprits are the oils or petroleum products. These materials in slight amounts will impart an oil or kerosene flavor to a wide variety of fish and shellfish,

FIGURE IV.5.3

FACTORS AFFECTING ESTUARINE DISSOLVED OXYGEN CONCENTRATION



including mullet, mackerel, oysters, clams, and mussels (Figure IV.5.4).

Another source of tainting substances directly related to organic waste discharges can develop when some areas the receiving waters reach septicity, i.e., all of the dissolved oxygen is depleted. Under such anaerobic conditions the decay of the benthic sludge deposits can result in the production of hydrogen sulfide, which has a very strong "rotten egg" odor. This gas, highly soluble in water, causes a black discoloration of bivalve shells and imparts an offensive taste and odor to their flesh when water carrying it moves across shellfish beds.

HEAVY METALS

The heavy metal salts are fairly soluble and stable in solution. Consequently, they will persist for extended lengths of time. Many of these are highly toxic to the aquatic biota. Since many marine organisms accumulate and concentrate substances within their cell structure, the presence of these metals in small concentrations can have deleterious effects. Table IV.5.1 lists the more common metals that are of environmental concern (IV-5-1).

The toxic concentrations listed in the table represent the lowest values for the particular species tested and not absolute minimums. Also, these toxic levels do not consider the synergistic effect that

TABLE IV.5.1
Characteristics of Common Metals of Concern
in the Estuarine Environment

Metal	Chemical Symbol	Natural Concentration in Sea Water (Mg/l)	Concentrations in Marine Organisms		Range of Concentrations that have Toxic Effects on Marine Life (mg/l)
			Plants(mg/l)	Animals(mg/l)	
Silver	Ag	.0003	0.25	1 to 3	Highly Toxic
Arsenic	As	.003	30.0	0.005 to 0.3	2
Cadimum	Cd	.08	0.4	0.15 to 3	0.01 to 10
Chromium	Cr	.00005	1.0	0.2 to 1.0	1.0
Copper	Cu	.003	11.0	4 to 50	0.1
Mercury	Hq	.00003	0.03		0.1
Lead	Pb	.00003	8.4	0.5	0.1
Nickle	Ni	.0054	3.0	0.4	0.1
Zinc	Zn	.01	150.0	6 to 1500	10.0

may occur with the presence of other metals. For example, the toxic effects of mercuric salts are accentuated by the presence of trace amounts of copper. The table does indicate the minute quantities of metal salts that can damage an estuarine system.

INORGANIC NUTRIENT SALTS

Aquatic life forms require trace amounts of some minerals and vitamins for growth and reproduction. Elimination of such materials from the environment or their reduction below minimum levels can limit the growth and reproduction of some biota. Conversely, an oversupply of all necessary trace mineral salts and vitamins can retard growth or stimulate it; providing satisfactory conditions of temperature, salinity, and dissolved oxygen also exist. An oversupply of inorganic nutrient salts, such as those of nitrogen and phosphorus, may be associated with drastic shifts in the composition of the aquatic community.

There may be shifts in population as the growth of one kind of life is stimulated more than that of others by additional nutrients, there may be increases in the general productivity of the entire ecosystem, or there may be no changes at all if one necessary factor is missing. When there is excessive growth with associated changes in distribution patterns and predator-prey relationships, some organisms may reach a state of "nuisance growths." This condition is defined as a density of growth that interferes with a desirable water use or the growth and reproduction of organisms desirable to

man. Examples of these situations are: (1) excessive drifting plant growths that make bathing beaches unattractive, produce unpleasant odors, foul the bottoms of boats, and spoil the esthetic appearance, and (2) dense populations of rooted aquatics which interfere with the movement and reproduction of fish (Figure IV.5.5).

In any case it must be stressed that some other environmental condition, and not nutrients alone, may be the controlling factor in such growths. The estuarine ecosystem is highly complex; its composition is dependent on a large number of variables, many of which are as yet not understood.

PATHOGENIC ORGANISMS

One unfavorable consequence of municipal and some industrial wastes is the contamination of the receiving environment with bacteria, viruses, and other pathogens with public health significance. The organisms, especially those from the intestines of warm blooded animals, frequently persist for sufficient periods of time and distance to pose a threat to the health and well-being of unsuspecting water users. Secondary channels of exposure to these organisms exist through the contamination of shellfish which can be harvested for food.

Multiple use of any estuarine zone requires careful consideration of the potential for contact with disease-producing agents. The

problem of finding pathogenic organisms in water is difficult. The methods available for determining the numbers of these micro-organisms in sewage and receiving water are not practical for routine use; nor is it possible to decide which organisms should be included in the testing procedures.

Evaluation of the microorganism density in water receiving waste discharges is based on the test for the total number of viable coliform bacteria present. This test procedure may be further extended to differentiate between the total numbers and those of probable fecal origin. The coliform bacteria in this instance are used strictly as indicator organisms. Although the coliform organism has been associated with infant diarrhea, it is generally considered as non-pathogenic in water. The organism is present in fecal material in large numbers, is highly viable in water, and is relatively easy to identify. The use of an indicator organism is justified on the premise that if coliforms of fecal origin are present, other pathogens of fecal origin probably are present also.

Although most human enteric pathogens do not survive for extended periods outside the host's body, evidence indicates that they may remain sufficiently viable in all types of aquatic environment to reinfect healthy individuals. Although considerable investigative work has been done on fresh water and on oceanic water, many questions are yet to be answered where the two meet in the estuarine zone.

Some of the factors affecting the survival of pathogenic organisms are:

(1) Environmental conditions such as salinity, temperature, amount of sunlight, and degree of dilution.

(2) Biological agents antagonistic to the survival of the waste borne organisms.

(3) Bacteriophages or viruses.

(4) Protozoan and other lower animals which consume pathogens for survival.

(5) Sedimentation and adsorption of pathogens with and by particulate matter in the receiving water.

(6) The amount of nutrient material available to support or stimulate multiplication of the organisms.

The presence of the coliform organisms, especially the fecal coliform, is an index to the degree of public health hazard. The two main avenues of exposure for humans in the estuarine environment are through body contact during recreation and through ingestion of contaminated food harvested from the estuary. In the former, the problem becomes one of balancing reasonable safeguards for public health and well-being against undue restrictions on the availability of waters for contact recreation. In estuarine recreation water, this problem is complicated by the lack of definitive epidemiological studies correlating the incidence of waterborne disease with degrees of bacterial pollution. To develop rational bacterial standards for contact

recreation, the most promising approach appears to be through intensive monitoring of indicator organisms coupled with salinity studies.

Shellfish contamination presents another problem in that the major concern is the ingestion and harboring of pathogenic enterovirus and bacteria by the organism. These viruses can then be passed on to a human host, especially if the shellfish are eaten raw. The relationship between the densities of coliform indicator organisms and the presence of enteroviruses is still ill-defined and needs further definitive investigation to assure the adoption of rational public health protecting criteria. At present shellfish closures are based on very stringent coliform bacteria concentration standards designed to provide a safety factor to insure public health.

TOXIC MATERIALS

Among the waste products frequently introduced into the estuarine environment are some directly toxic to marine organisms. Toxic materials may exhibit a short catastrophic impact or a more subtle long-term interference with growth and reproduction processes. The end result is the creation of a biological desert in which no organism can survive.

The short-term catastrophic type of toxicity usually results from an accidental spill or slug discharge of materials into the water. The impact is immediate and the results are dramatic.

The long-term type of toxicity is manifested through the gradual destruction of the natural biota. The effects of sub-lethal concentrations of toxic materials are amplified through biological magnification. Many animals, especially shellfish, can remove these materials from the environment and store them in their tissues. This magnification phenomenon has been documented with such pollutants as pesticides, heavy metals, and radionuclides. The body concentration of the toxicant may reach such a level that death results in the host organism when the material is released to the blood stream by physiological activity. Any higher carnivore consuming an organism with high tissue concentrations of toxic materials may be subject to acute or fatal poisoning. Table IV.5.2 lists the biological magnification factors of five mollusks for specific pesticides (IV-5-2).

The pesticide group is of particular concern in the estuarine zone. Estuaries are the terminus for most of the major river systems, and as such they tend to concentrate the waterborne materials carried in by the large terrestrial drainage systems. The biological magnification capability of estuarine animals significantly increases the hazard and destructive potential of any contributed pesticides. Table IV.5.3 shows the concentration of selected pesticides that will kill 50 percent of exposed shrimp within 48 hours. Shrimp are one of the most sensitive groups of marine organisms (IV-5-1).

TABLE IV.5.2
Magnification Factors of Five Selected Mollusks*

Pesticide	Magnification Range
Lindane	10 - 250
Endrin	500 - 1250
Methoxychlor	300 - 1500
Dieldrin	700 - 1500
Heptachlor	250 - 2500
Aldrin	350 - 4500
DDT	1200 - 9000

* Mention of any trade name in this report does not constitute endorsement of the product by the Federal government.

Many other materials have a toxic effect on estuarine biota. These materials may be present in various industrial wastes or be by-products of interaction within the estuary. Examples are cyanides from metal-plating wastes and sulfides from the anaerobic decomposition of sewages and industrial wastes.

Wastes from the chemical industry are highly variable and potentially toxic. Ever-changing chemical technology leads to many new products, each creating a new complex waste disposal problem.

Included in the consideration of toxic materials are radionuclides discharged to the estuarine waters. Ionizing radiation, when absorbed

TABLE IV.5.3
The 48-hour TLm for Shrimp for Selected Pesticides
(in micrograms/liter)

Organochloride Pesticides			
Aldrin	0.04	Dieldrin	0.6
BHC	2.0	Endosulfan	0.3
Chlordane	2.0	Methoxychlor	4.0
Endrin	0.2	Perthane	3.0
Heptachlor	0.2	TDE	3.0
Lindane	0.2	Toxaphene	3.0
DDT	0.6		
Organophosphorous Pesticides			
Coumaphos	2.0	Naled	3.0
Dursban	3.0	Parathion	1.0
Fenthion	0.03	Ronnel	5.0

TLm = concentration which will kill 50 per cent of exposed animals.

in living tissue in quantities substantially above that of natural background, is recognized as injurious (IV-5-1). Since some isotopes may be extremely long-lived, and radionuclides may be cycled through the food chain or recycled to the environment if the host expires, the biological magnification factor is important. The potential consequences of each particular radioisotope discharge must be evaluated individually. The best rule is to minimize the amount of these materials cycling in the environment.

Toxic materials directly kill the biota, interact in the food chain, or deleteriously affect the reproduction or growth processes. The ultimate damage is to stress or eliminate parts of the energy-conversion chain in the estuarine environment (Figure IV.5.6).

HEAT

The preceding discussion emphasized the many environmental factors affecting the impact of various types of wastes on the estuarine environment. Water temperature was mentioned in almost every instance. Thus the addition of large quantities of heat from industrial cooling water constitutes a form of pollution which must be considered (Figure IV.5.7).

The impact of heat pollution on the environment appears in several different ways:

(1) Heat affects the physical properties of water such as density, viscosity, vapor pressure and solubility of dissolved gases. Consequently, such processes as the settling of particulate matter, stratification, circulation, and evaporation can be influenced by changes in temperature. Since the solubility of oxygen in water decreases as temperature increases, thermal pollution reduces the oxygen resources. Most aquatic organisms depend on dissolved oxygen to maintain growth and reproduction.

(2) Heat affects the rate at which chemical reactions progress, and it can speed up the formation of undesirable compounds or change dynamic chemical equilibria. It also affects biochemical reactions and can result in a more rapid depletion of the oxygen resources. If sufficient heat is added, temperatures can be elevated enough to sterilize the environment by killing all living organisms.

(3) Environmental temperatures are important to the living resources. Physiological processes such as reproduction, development, and metabolism are temperature dependent. The range of many species of fishes and the species composition of communities are governed to a great extent by the environmental temperature. Temperature anamolies also can block the passage of anadromous fish, greatly reducing future populations.

(4) An increase in temperature can result in synergistic action; that is, the simultaneous effects of separate agents is greater than the total sum of individual effects. Prime examples are increased toxicity of some materials, increases in susceptibility of fish to diseases, and increased virulence of fish pathogens.

(5) Thermal pollution affects other aquatic organisms such as the aquatic plants, the benthos, and the bacterial populations. Increased temperatures may reduce the numbers of

species in the community and stimulate excessive populations of individual species to nuisance conditions.

The entire ecosystem may be stressed by thermal pollution. The amount of damage is dependent on the resulting temperature of the environment and the species composition of the biotic community. The total range of detriments should be carefully considered on an individual case basis before heat is released to the environment.

SEDIMENTATION

The estuarine zone serves as a repository for the suspended material carried by the Nation's rivers. From a pure mass standpoint, a significant percentage of these materials is comprised of the sediment load which is measured in billions of tons annually. For example, a conservative estimate of the sediment carried by the Mississippi River through its delta complex is five hundred million tons annually.

Man's activities may purposely or inadvertently upset the natural balance of inflow, deposition, and outflow. If upstream erosion is increased due to poor land management practices, the load carried in suspension will increase. Conversely activities along the coast can result in increased shore erosion, removing more sediment than is contributed. The primary pollutional problem from sediment, however, results from increased influx and accelerated deposition.

The detrimental effects of sedimentation are reflected in an impairment of uses such as navigation, recreation, water supply, and fish propagation. Navigational interests are damaged by the accretion of materials in ship channels and near docking facilities; millions of dollars are expended each year in channel dredging to maintain navigation. Recreational interests suffer from the loss of safe boating water, increased maintenance of marinas, and from the loss of fishing areas (Figure IV.5.8). The cost of diversion and use for water supply purposes may be significantly increased because of the need to remove excess sediment.

Fishery loss stems from the destruction of suitable habitat. This damage results from loss of suitable breeding areas, loss of food chain organisms because of change in benthic characteristics, and fish kills from excessive turbidity.

Channel maintenance adds to the sedimentation problem. The cost of dredging is greatly influenced by the selection of spoil areas; if the spoil is redeposited in the water environment, changes in bottom characteristics are transferred to other areas, thus expanding the scope of impact. Dredging spoil disposal results in increased turbidities as well as changing bottom configuration. Both occurrences can adversely affect the aquatic habitat. Natural sedimentation is an integral part of the estuarine environment. Man-made sedimentation problem is a form of pollution that is significant in terms of dollar damages and must be considered in the overall management scheme.

CATASTROPHIC ACCIDENTS

One great threat to the estuarine ecosystem is the ever-present chance of a catastrophic spill of oil or other hazardous materials. The large volumes of petroleum and chemical products transported through the estuarine zone by ships, barges, pipelines, trucks, and railroads present a continuing opportunity for accidental bulk spills. The consequences of these spills depend on the amount and type of material released and the characteristics of the receiving water. They may range in magnitude from tragic loss of human life to little more than economic loss for the transporter (Figure IV.5.9).

When a significant spill occurs, the results can be dramatic. A large quantity of material is suddenly disgorged into the system; the fate of this material depends on its miscibility with water, its solubility in water, and its density, stability, and volatility. The fate of the environment depends on what segments contact the material and the inherent toxicity of the material.

The potential magnitude of the problem is staggering. The quantities and varieties of oils and other hazardous materials transported or stored are reflected in the following statistics:

(1) Almost 4 billion barrels of petroleum and natural gas liquids are used annually in the United States.

(2) Twenty-five billion pounds of animal and vegetable oils are consumed or exported annually.

(3) Almost 80 billion pounds of synthetic organic chemicals are produced annually by some 12,000 chemical companies. These chemicals, many of which are toxic or have unknown effects on aquatic or human life, range from everyday food flavorings to lethal pesticides.

The damage to water uses can be demonstrated by consideration of a catastrophic oil spill. Water birds are attracted by the slick on the surface. Once they contact the oil, their feathers become matted and oil soaked. The birds either drown, are killed by toxicosis from ingested oils or by exposure from the loss of body insulation, starve to death from inability to fly and search for food, or are eaten by predators (Figure IV.5.10).

Fish become coated with oil and their gills become clogged, resulting in death. If the exposure is sublethal, their flesh becomes tainted rendering them unfit for human consumption for a considerable time. Toxic oil fractions in the water can kill the larval and adult forms of invertebrate marine life necessary for a balanced ecosystem. Aquatic vegetation is destroyed. An extreme fire hazard can exist, depending on the type and extent of the oil blanket. Recreational use of the water is impaired. Swimmers become coated with oil which is difficult to remove; boat hulls are stained; beaches with oil deposits become virtually unusable. Apart from the physical damage, there is also a esthetic damage. Noxious odors may permeate the shoreline areas; and waterfront properties are despoiled (Figure IV.5.11).

The direct damage is not the total economic impact. The cost of cleanup must be added and is considerable. The ever-present threat of a catastrophic spill places the estuarine treasure house of resources in jeopardy.

DELIBERATE PHYSICAL MODIFICATION

Building a bridge, dredging a channel, and filling land for a housing development are not ordinarily regarded as forms of pollution, yet they can cause damage to the biophysical environment far more devastating than the most potent industrial or municipal waste.

Physical modification is permanent; once an estuarine habitat is destroyed by dredging or filling, it is gone forever. No waste treatment can correct or even minimize the damage. The destruction of a marsh or part of the estuarine shallows has an obvious effect on habitat value, but equally severe damages can be associated with apparently minor physical alterations.

The effect any pollutant has on an estuarine environment depends on where it goes, how strong it is, and how rapidly it is assimilated or flushed out of the environment. These conditions depend on water movement and circulation patterns, which are in turn governed by the relationship of tide and river flow to estuarine shape and size. Dredging of new or deeper navigation channels, building of causeways or jetties, and even construction of bridge piers can cause subtle changes in water movement that can alter the balance of environmental

conditions in an estuarine system and result in gradual undesirable changes in the ecosystem.

Table IV.2.10 shows the amount of estuarine habitat lost by filling; Table IV.2.11 lists the major river flow regulation structures affecting rivers in the estuarine zone; Table IV.5.4 gives a general idea of the numbers of miscellaneous structures in the estuarine zone. These three tables indicate only of the extent of modification, not of its effects. While destruction of habitat by filling is measurable, the environmental changes wrought in an estuarine system by external flow regulation or by internal structures are so closely associated with its morphology that generalization is impossible. Table IV.5.4 shows that there are in the estuarine zone 752 jetties, dikes, and breakwaters averaging nearly 1000 feet in length. These are all solid structures specifically designed and placed to modify flow patterns. While habitat damage may have been considered in the design of many of these, it is unlikely that effects on the estuarine environment were considered seriously in the placement of many of the 989 causeways and pier bridges within the estuarine system.

Physical modification of estuarine systems may enhance the usefulness of the biophysical environment. In fact, many modifications are made deliberately to improve or protect an estuary for a specific use, but often without consideration of the effects on other uses. The side effects of such modifications may be good or bad, depending on local conditions. For example, the piers and abutments that support

TABLE IV.5.4 ARTIFICIAL MODIFYING STRUCTURES

BIOPHYSICAL REGION	JETTIES, DIKES & BREAKWATERS		CAUSE-WAYS	PIER BRIDGES	DREDGED CHANNELS		TOTAL STRUCTURES (EXCLUDING CHANNELS)
	NUMBER	LENGTH (AV--FT)	NUMBER	NUMBER	NUMBER	LENGTH * (FEET)	
NORTH ATLANTIC	60	2600	48	48	146	48640	156
MIDDLE ATLANTIC	171	160	53	58	269	18340	282
CHESAPEAKE BAY	63	N. A.	19	37	37	99724	119
SOUTH ATLANTIC	44	1130	43	46	68	40746	133
CARIBBEAN	31	900	32	34	43	18500	97
GULF OF MEXICO	196	260	146	170	308	22702	512
PACIFIC SOUTHWEST	37	1100	22	30	55	12820	89
PACIFIC NORTHWEST	51	60	30	37	91	8800	118
ALASKA	52	930	44	41	73	0	147
PACIFIC ISLANDS	37	1140	27	24	75	13000	88
TOTAL	752	930	484	525	1165	283272	1741

* FOR DEPTHS GREATER THAN 35 FEET.

REFERENCE: NATIONAL ESTUARINE INVENTORY

SOURCE: U.S. ARMY CORPS OF ENGINEERS

bridges are frequently excellent fishing grounds, yet the same piers can have adverse effects on water movement.

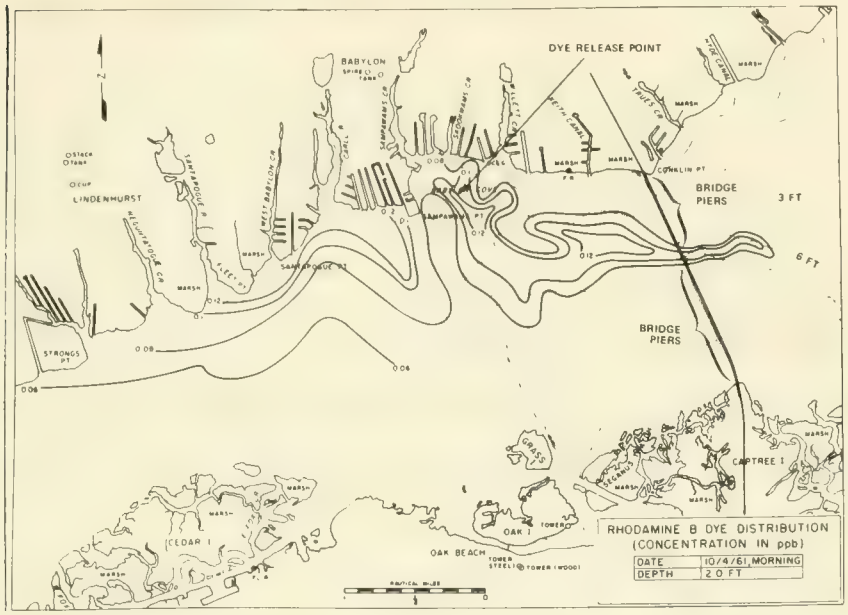
A Public Health Service study of Great South Bay on Long Island, N.Y., in 1961 found that water circulation west of the Bay Bridge was greatly restricted, dye tracers showed that the bridge piers acted as a partial barrier to water movement. Figure IV.5.12 shows the Bay Bridge and schematically illustrates the movement of dye near the Bridge. This study concluded that the restricted circulation west of the Bay Bridge was a contributing factor to the degradation of water quality in this area (IV-5-3).

The insidious nature of environmental damage associated with physical modification makes it difficult to assess and predict the effects of specific physical changes on the estuarine environment. Three examples of the results of physical modification illustrate how flow regulation can damage an estuary, what the results of progressive filling can do, and how physical modification can improve the environment.

Charleston Harbor, South Carolina

As part of the national plan to minimize unemployment during the depression of the 1930's, the South Carolina Public Service Authority was formed. Its purpose was to build a large dam, water supply, flood control, navigation, and recreation complex that would

FIGURE IV.5.12 WATER MOVEMENT NEAR A PIER BRIDGE, GREAT SOUTH BAY, LONG ISLAND, N.Y.



TOP: DYE MOVEMENT THROUGH THE BAY BRIDGE ON A WINDLESS EBB TIDE. GREATEST WATER DEPTH NEAR THE BRIDGE WAS 9 FEET.

BOTTOM: RECENT PHOTOGRAPH OF BAY BRIDGE. NOTE THAT DYE MOVEMENT WAS DIRECTLY TOWARD THE OPEN PART OF THE BRIDGE. (SECOND BRIDGE WAS BUILT AFTER THE 1961 DYE STUDY)

generate employment opportunity. This complex, called the Santee-Cooper Project, involved the diversion of the Santee River into the Copper River through Lake Marion and Lake Moultrie. The outflow from Lake Moultrie would go through a hydroelectric plant into the Cooper River. In addition to the creation of large recreation lakes the project would open a navigation channel to Columbia, S. C. It was felt the increased flow in the Cooper River would benefit Charleston Harbor, because it would help flush pollutants from the harbor and improve water quality (Figure IV.5.13).

The project was completed and placed in operation in 1942. By 1947, shoaling rates in the Harbor had increased to the point where dredging was a full time operation. Hydraulic model studies found the answer to the increased channel maintenance; the higher fresh water inflow had markedly increased salinity stratification and resulted in the formation of a salt wedge. Particles were entrapped in the wedge, and deposition of sediments increased.

The intended modification changed the circulation patterns and instead of improving conditions in the Harbor, created more serious problems. There is now a recommendation to divert the flow back into the Santee. The net long run effect, regardless of the outcome of this recommendation, will be the complete alteration of two estuarine systems with an unknown total effect on the ecosystem (IV-5-4).

San Francisco Bay, Calif.

San Francisco Bay is the largest of all natural harbors on the Pacific coast south of Puget Sound (Figure IV.5.14). The fresh water inflow to San Francisco Bay is primarily the drainage from the central valley of California; the Sacramento River from the north and the San Joaquin from the south form a huge rich delta which is connected to the Bay. The overall size not including the tidal delta area is about 435 square miles at mean high water.

In 1850, when California was admitted to the Union, San Francisco Bay was even larger than it is today. More than 300 square miles of marshlands along its shores gave it the appearance of being extraordinarily vast, particularly during maximum spring tides when the Bay waters flooded far inland, drowning all but the tips of reeds and marsh grasses. Since those early days more than 240 square miles of the salt marshes have been reclaimed, chiefly for agriculture and salt ponds. In addition, approximately seventeen square miles of tidal and submerged lands have been filled, mostly along the waterfronts of San Francisco, Oakland, and Richmond; in Richardson and San Rafael Bays in Marin County; and along the northern bayshore of San Mateo County. And yet the Bay still seems so immense that it intrigues many minds with the possibilities of reclaiming additional square miles for industrial and residential developments, recreation areas, airports, highways, and commercial establishments.

The Bay presents few obstacles to reclamation through land fill. It is shallow throughout much of its area, with 80 percent of the water less than 30 feet deep and 70 percent less than eighteen feet deep at low tide references. About 248 square miles of tidal and submerged lands in the Bay are still susceptible to reclamation. If these areas were filled and used for urban purposes, only 187 square miles of the Bay would remain as deepwater channels for ships and many portions of the Bay would be reduced almost to rivers.

This example shows the magnitude of reclamation that can occur without consideration of future consequences. A total damage assessment has not been made, but there has been a drastic decline or elimination of clam and shrimp fishing within the Bay. When nursery areas of the size of San Francisco Bay are damaged this damage must be reflected in the life of the adjacent coastal waters (IV-5-5).

Mission Bay, San Diego, Calif.

Mission Bay in California is one of the better examples of deliberate modification to intensify use. In fact, this unique case demonstrates what can be accomplished through coordinated Federal, State, and local planning and construction. The end result has added considerable value to the community and has preserved a portion of the estuarine environment in a metropolitan area (Figure IV.5.15).

Mission Bay and San Diego Bay lie in the delta of the San Diego River. Prior to about 1825 the river would switch channels and flow into one or the other depending on the whims of nature. Between 1825 and 1877, history shows the San Diego River Channel emptying into San Diego Bay. Since San Diego Bay was one of the best natural harbors on the Pacific coast, the shipping interests became very concerned over the sediment load deposited in the harbor. It was felt that if this sedimentation process were not controlled, the Bay would become too shallow for navigation.

Consequently, in 1877 the San Diego River was permanently diverted into Mission Bay. The period from 1900 to 1950 was one of exceptional growth for Southern California. Private and Federal developments in the San Diego Bay portion of the delta were of sufficient magnitude to warrant flood control works on the River. Subsequently, a separate flood control channel, which empties into the ocean, was built for the San Diego River, and some navigation dredging was done in Mission Bay.

During the same period of time (1900-1959), changes were occurring in Mission Bay. In 1929, California incorporated Mission Bay into its State park system. In 1945, title to the tidelands and submerged lands was granted to the city of San Diego. The city passed a $2 million bond issue for improvement of Mission Bay. It also cooperated

with the Corps of Engineers, complying with all conditions necessary to obtain a multipurpose flood control and navigation project for the San Diego River and Mission Bay.

Since 1946, the venture has accomplished a completely separate flood channel for the San Diego River, a superbly planned recreational development in Mission Bay including private investments totalling over $22,500,000 for support and service facilities, an orderly preservation of habitat necessary for coastal fisheries, and open water recreation areas with water quality sufficiently high for all water-contact sports. The Bay has been zoned for various activities, banks have been stabilized, and beaches have been created. All of this area is just a few minutes drive from the center of San Diego.

The total dredging effort in Mission Bay since 1946 has cost over $6,500,000 and over 9,500,000 cubic yards of material have been removed. Mission Bay stands today as a shinning example of what determined community effort can achieve (IV-5-6, IV-5-7).

SECTION 2. SOURCES OF POLLUTION

Nearly all of man's activities can result in environmental degradation. The pollutants and polluting conditions outlined in the preceding section are rarely unique to a particular use or specific activity, but they result from man's existence in the estuarine zone as well as his use of it. The major sources of pollution described in this section fall into three broad categories:

(1) Those sources associated with the extent of development of the estuarine zone, including waste discharges from municipalities and industries, and land runoff from urban and agricultural land.

(2) Those sources associated with particular activities of great pollutional significance, specifically dredging and filling, watercraft operation, underwater mining, and heated effluent discharges.

(3) External sources having impact derived through flow regulation and upstream water quality.

MUNICIPAL WASTES

Over eight billion gallons of municipal wastes are discharged daily into the waters of the estuarine zone. While most of this volume is domestic sewage, many municipal waste discharges also contain

significant amounts of industrial wastes, which may add to their variability and complexity.

Municipal waste discharges have four important effects on receiving water quality.

(1) The decomposable organic matter of municipal waste discharge exerts a demand on the oxygen resources of the receiving water. This demand can result in depletion of dissolved oxygen to the point where desirable biota cannot tolerate the environment; they disappear or are killed. Complete depletion can result in noxious odors with destruction of esthetic values.

(2) Municipal wastes may contain pathogenic organisms dangerous to human beings. The coliform bacteria measurement is an index of the possible presence of pathogens. The basic premise is that if fecal indicator organisms are present, there is a high probability of pathogens being present; this condition is a public health hazard for anyone ingesting or contacting the water. There are many documented cases of waterborne epidemics and water transmitted diseases to support the health hazard premise.

(3) The settleable material in municipal wastes may be deposited on the bottom, resulting in large sludge banks of organic content. These sludge banks can also deplete the oxygen resources through biochemical reactions. The suspended materials, if sufficient in quantity, can reduce the depth to which sunlight penetrates, altering that portion of the ecosystem dependent upon photosynthetic activity.

(4) Dissolved salts can make the water less desirable for other uses and the fertilizer or nutrient portions are sometimes implicated in stimulating nuisance growths of algae and other aquatic plants. These aquatic growths in an enriched stream can cause severe fluctuations in dissolved oxygen concentrations and can interfere with other legitimate uses.

Table IV.5.5 summarizes municipal waste discharge volumes into the biophysical regions. While the Middle Atlantic region has by far the largest volume of municipal waste discharge, the potential impact on the estuarine zone is greatest in both the Pacific Southwest and in the Pacific Islands because of the small estuarine water areas in these two regions. This potential impact is lessened by the ability to use deep ocean outfalls, an approach made practicable by the narrow continental shelf in these regions.

Table IV.5.5
Municipal Waste Discharges In The
Estuarine Zone

Biophysical Region	Total Volume of Municipal Wastes(1)	Percent of Sewered Population with Secondary Treatment, 1968(2)	Volume per Square Mile of Estuarine area(gals./day)
North Atlantic	550	25	160,000
Middle Atlantic	3500	60	680,000
Chesapeake Bay	640	90	140,000
South Atlantic	270	75	70,000
Caribbean	160	N.A.(3)	220,000
Gulf of Mexico	760	75	70,000
Pacific Southwest	1900	30	2,380,000
Pacific Northwest	390	50	200,000
Alaska	13	25	1,000
Pacific Islands (Hawaii Only)	85	25	5,700,000
Total	8300	50	180,000

(1) Based on 150 gallons per capita per day of total population in Standard Metropolitan Statistical Areas, 1965. Volume in mgd.

(2) Data from USDI, FWPCA, "Cost of Clean Water, 1969."

(3) N.A. means data are not available.

Sewage treatment reduces and alters the impact of municipal waste on the environment. Primary treatment with chlorination removes part of the decomposable organic material, removes nearly all of the settleable and suspended solids, and almost eliminates the possibility of pathogens in the effluent. Secondary treatment can almost eliminate decomposable organic material, and some special processes can eliminate certain dissolved salts. About half the municipal wastes discharged to estuarine waters receives secondary treatment, with the most extensive use of secondary treatment being in the Chesapeake Bay estuarine region.

INDUSTRIAL WASTES

Associated with the major metropolitan developments are large numbers of industrial complexes with their attendant waste products. Many of these wastes, especially from the chemical and petroleum industries are so complicated that it is difficult both to identify them and to assess their effects on the receiving streams.

Table IV.3.2 gives a summary of the major manufacturing industries in the estuarine zone. Table IV.5.6 presents the basic characteristics of wastes from each major industrial category. Table IV.5.7 and Table IV.5.8 show the waste discharges and levels of waste treatment associated with this industrial development.

TABLE IV.5.6 POLLUTION CHARACTERISTICS OF INDUSTRIAL WASTE

Type of Industry	Origin of Major Wastes
Ordance and Accessories	Power plant, stack washing, leaching from ashes, lubrication and hydraulic oil spillage, surface cleaning, treating, and painting, plating operations, trimming and buffing operations, milling with cutting oils. Repair and rework operations.
Food and Kindred Products	Washing of raw products, slaughtering, separation of skins, peels, pits, scales, feathers and other inedible fractions of crude products, rendering of fats, blanching, cooking operation, curing and pickling operations, byproducts of too little value to market, spills, floor and equipment cleaning, diffusion extraction operations, wet grinding operations, steep tank liquors, still bottoms and cooling water.
Tobacco Manufactures	Mainly dry operations, some incidental cleanup operations.
Textile Mill Products	Wool scouring, desizing operations, cleaning, dyeing and bleaching.
Apparel and Other Finished Products Made from Fabrics and Similar Materials	Dry Operations.
Lumber and Wood Products, Except Furniture	Leaching of logs being floated to mills and held in ponds for milling. Sawdust is potentially a heavy polluting agent if disposed so that it is washed into surface waters by storm runoff or if stored so that leachate reaches surface waters. Preservatives and glues.
Furniture and Fixtures	Water curtain utilized to pick up waste from varnishing, painting and finishing operations
Paper and Allied Products	Pulping operations, including leaching of logs and chips, chemical pulping treatments, and bleaching operations. Debarking processes. Condensate from reagent recovery evaporators. Disposed fibers from paper-making. Glue, ink and coloring agent spills. Heavy contamination from production of Naval stores.
Printing, Publishing, and Allied Industries	Mainly dry operation. Some waste from glueing and preparation of plates.
Chemicals and Allied Products	Bleeding of recycle streams to avoid buildup of impurities, wet scrubbing of stacks and condenser exhausts, side reactions in many processes, acid, alkaline and organic extraction agents, impurities in raw materials, catalysts, unreacted monomers and other feed reagents, stabilizers, contaminated cooling water, dispersing agents, spent culture media, cleanup and spills.
Petroleum Refining and Related Industries	Crude oil and process brines, cooling water from heat exchangers. Leaky heat exchange equipment. Side reaction products from cracking and synthesizing operations. Fractions that escape collection by distillation columns. Stack washing, storage tank drainoff and spills.
Rubber and Miscellaneous Plastic Products	Most processes dry. Cooling water used in considerable quantity. Acid or alkali digestion of reclaimed rubber and washing of digested product. Acid, salt and alcohol coagulants for latex processes. Wash water for latex processes. Lubricating and hydraulic oil spills. Reagent spills and cleanup operations. Latex and reclaim processes greatest polluters.
Leather and Leather Products	Wastes occur almost exclusively in tanning and finishing operation. Salting of hides, leachate and scraping from hides, green fleshing, unharing, bating, pickling, degreasing and tanning.
Stone, Clay, Glass and Concrete Products	Grading of sand, clay and other mined components is major wastewater contamination source.
Primary Metal Industries	Cleaning and pickling acids. Various cleaning solutions and detergents. Oils for forming operations. Coke quenching and stack washing water, cooling water, molding and ore sands, machining operations. Leaching agents for ores, flotation process, ore purifying.
Fabricated Metal Products, Except Ordance, Machinery, and Transportation Equipment	Lubricating and hydraulic oil spills from processing equipment. Machining operations, flue gas washing, metal cleaning operations paint spraying operation, electroplating anodizing.
Machinery Except Electrical	Water wash of stacks, blowdown of boiler, cooling tower residues, ion exchange wastes, drainage from cinder and ash dumps, cutting oils, lubricating compound spills and rinse, hydraulic oil leaks, sand blast dusts, dispersions, metal chips, metal surface cleaners, corrosion prevention reagents, painting and plating operations.
Machinery, Equipment and Supplies	Metal forming operations, metal cleaning, plating and painting operations. Cutting and drilling of insulators.
Transportation Equipment	Stack washing, cutting oils, spills of lubricating oils and hydraulic oils, pickling and cleaning operations, plating operations, cooling water, blowdown of boilers, corrosion protection, painting operations, and sanding.

TABLE IV.5.6 POLLUTION CHARACTERISTICS OF INDUSTRIAL WASTE (continued)

Major Wastes Characteristics	Treatment
Suspended solids as fly ash, metal powder, paint solids, domestic wastes and miscellaneous cleanup solids. Cutting, lubricating and hydraulic oils. Detergents and organic cleaning agents. Cyanide and heavy metals.	Plant control. Oil separators, flocculation and sediment action. Cooling systems. Buffer lagoons. Aerobic biological treatment. Use of municipal system.
Heat, high BOD and suspended solids, detergents, nitrogenous substances, fat, organic acids, salts, large operations cause severe nuisance growth, animal pathogen hazard.	Process control, keeping water use at a minimum and exclusion from waste-water screens, fat separators, sedimentation, biological treatment and municipal plants, separation of solids for landfill or barging to sea, disinfection.
Minor problem.	Municipal plants.
High BOD, heat and suspended solids, acids, bases, bleaching agents, detergents and dyes with high coloring activity. Many waste components have biocidal action.	Process control, physical, chemical biological, particularly activated sludge and aerated lagoon. Municipal plant.
Very little water pollution	Municipal plant
Large amount of BOD in leachate from logs and from sawdust. Some biocidal contaminant in leachate and in preservative spills	Process control
Solvents, pigment, varnish solids. High BOD and biocidal components	Process control chemical, sedimentation, bio-oxidative, municipal plant
Very high suspended solids, BOD, heat, oil, acid, alkali, color and biocidal component problem. The volume is large and treatment difficult	Process control, chemical precipitation, neutralization, sedimentation and centrifugation. All types of biological treatment. Lagoons, landfill and irrigation. Controlled discharge on outgoing tides
Some BOD glueing and acidic metal solutions from plate preparation. Very limited source of cyanide from plating operations.	Process control, chemical, physical, municipal plant
Acids, alkalies, salts, flammable and biocidal organic compounds in great variety, suspended solids, oils, phosphorous, sulfides, cyanides, heavy metals detergents, elastomer dispersions and fluorides. High BOD loads.	Process control, chemical, neutralization, oxidation, precipitation, sedimentation, oil separation, bio-oxidative treatment with adapted systems, particularly activated sludged and aerated lagoons. Many wastes require isolation and special treatment. Buffer lagoons help handle difficult loads. Burning of separated solids or oils.
Various oily components. Phenolic compounds. Sour waters containing sulfides and mercaptans. Ammonia. Cyanide. Pyridine. Spent caustic solutions. Various detergents. Hot streams. Various sludge components. Chromates. Biocidal agents. Chemicals that cause fish flavors, a major wastewater problem.	Physical, chemical, oxidation, cooling, neutralization, oil separation, sedimentation, bio-oxidation in adapted systems, particularly activated sludge and aerated lagoons. Flotation, electrostatic separators and centrifugation.
Large quantity of hot water. Sulfur zinc compounds and wide variety of biocidal organic compounds. Organic acids and BOD components. Discoloration from carbon black. Detergents and suspended solids.	Process control, physical, acclimated bio-oxidative system.
Salt, animal fluids, proteinaceous compounds, fat, suspended flesh, sulfide and ammonium salts, detergents, organic solvents, vegetable and chrome tanning agents. Very high BOD and nuisance promotion components. Components with biocidal action.	Process control, chemical coagulation, sedimentation, bio-oxidative treatments.
Suspended solids from mineral grading in large quantity, when mining associated with manufacture. Small amount of suspended solids from grinding and cutting operations.	Sedimentation.
Fly ash, metal chips and powder, iron salt solutions, acids, bases, chromium, variety of organic chemicals, cyanide, oils, detergents, sulfides, ammonia, fluorides and heat. Volume huge.	Process control, chemical, physical neutralization, precipitation, oil separation, flotation, magnetic separation, acclimated bio-oxidative systems particularly activated sludge and aerated lagoons. High speed mills and deteriorating ore quality leading to more waste. Deep wells. No separation of fluorides.
Oils, metals powder and chips, detergents, paint solvent and solids, chromic acid, phosphoric acid, cyanide and heavy metals.	Process control, chemical, sedimentation, oil separation, bio-oxidation, municipal plants
Suspended solids, oils, detergents, acidic metal salts, organic solvents, cyanide, ammonia, fluoride, phenolic compounds, phosphoric and chromic acids. Many substances unfavorable to aquatic organisms.	Process control, chemical, oil separation, sedimentation, bio-oxidation, municipal plant.
Metal chips and powder, other suspended solids, oils, acids, detergents, cyanide, heavy metals, paint solvents and solids. These industries are not regarded as heavy polluters but carry on operations that consistently lead to polluted water. Plating baths are a serious hazard and demand close control.	Process control, double tanking of cyanide baths, chemical, oil separation, sedimentation, bio-oxidation and municipal plant.
Oils, metal chips, detergents, acids, iron salts, cyanide, heavy metals, fly ash, paint solvent and solids and alkaline waste. Many components with biocidal activity.	Process control, chemical, physical sedimentation, oil emulsion, breaking and separation, special isolation and destruction of cyanide wastes, bio-oxidative treatment with acclimated systems.

TABLE IV.5.7 INDUSTRIAL WASTE DISCHARGES IN COASTAL STATES, 1963

STATE	TOTAL WASTE DISCHARGE		TREATED WASTE DISCHARGE		UNTREATED WASTE DISCHARGE		TOTAL WASTES TREATED
	NUMBER PLANTS	VOLUME (MGD)	NUMBER PLANTS	VOLUME (MGD)	NUMBER PLANTS	VOLUME (MGD)	PERCENT
MAINE	64	447	21	55	43	392	12
NEW HAMPSHIRE	40	96	12	14	28	82	15
MASSACHUSETTS	304	395	78	44	226	351	11
RHODE ISLAND	67	44	11	8	56	36	18
CONNECTICUT	209	319	65	25	144	294	8
NEW YORK *	565	1559	176	578	389	981	37
NEW JERSEY	421	1082	148	361	273	721	33
PENNSYLVANIA *		4041	10	1008		3033	25
DELAWARE	45	499	21	318	24	131	71
MARYLAND	143	1099	48	258	95	841	23
VIRGINIA	147	753	69	189	78	564	25
DISTRICT OF COLUMBIA							
NORTH CAROLINA	238	400	86	151	152	249	38
SOUTH CAROLINA	158	277	60	38	98	239	14
				296	80	638	32
GEORGIA	200	584	58	208	142	376	36
FLORIDA	116	630	59	219	57	411	35
ALABAMA	154	663	44	249	110	414	38
MISSISSIPPI	71	178	23	66	48	112	37
TEXAS	343	3986	169	737	174	3249	18
LOUISANA	171	2310	68	819	103	1491	35
CALIFORNIA	578	857	230	526	348	331	61
OREGON		414	49	93		321	22
WASHINGTON		934					
ALASKA		83		11		72	13
HAWAII		279		41		238	15
TOTAL	4034	21879	1505	6312	2668	15567	29

* INCLUDES SOME DISCHARGES TO THE GREAT LAKES & THE OHIO RIVER.

REFERENCE: NATIONAL ESTUARINE INVENTORY
SOURCE: U.S. DEPT. OF COMMERCE, BUREAU OF THE CENSUS
NOTE: THE ESTABLISHMENTS INCLUDED IN THIS TABLE ARE THOSE HAVING WATER USE OF 20 MILLION GALLONS OR MORE ANNUALLY. THIS REPRESENTS 97% OF TOTAL INDUSTRIAL MANUFACTURING WATER USE.

TABLE IV.5.8 WASTE DISCHARGES OF MAJOR WATER USE INDUSTRIES IN THE COASTAL STATES*
(VOLUME IN MGD)
1963

STATE	FOOD AND KINDRED PRODUCTS			PAPER AND ALLIED PRODUCTS			CHEMICALS & ALLIED PRODUCTS			PETROLEUM & COAL PRODUCTS			PRIMARY METALS INDUSTRIES		
	TOTAL	TREATED	UNTREATED	TOTAL	TREATED	UNTREATED	TOTAL	TREATED	UNTREATED	TOTAL	TREATED	UNTREATED	TOTAL	TREATED	UNTREATED
MAINE	3		3	395	25	370									
NEW HAMPSHIRE															
MASSACHUSETTS	30		30	123	30	93	45	19	30				30		30
RHODE ISLAND	5		5										11		11
CONNECTICUT	3		3	17	14	3	25		25				63		63
NEW YORK	*87	5	82	348	41	307	348	132	216				485	263	222
NEW JERSEY	41	11	30	66	30	36	192	22	170	359	88	271	85	3	82
PENNSYLVANIA	80	3	77	187	88	99	414	19	395	301	268	33	2811	597	2214
DELAWARE	6	3	3	11	11		115	8	107						
MARYLAND	36	3	33												
VIRGINIA	6	3	3	175	63	112	438	49	389				3		3
DISTRICT OF COLUMBIA															
NORTH CAROLINA	11	3	8	178	110	68	33	11	22				1		1
SOUTH CAROLINA	3		3				91	3	88						
GEORGIA	24	5	19	422	156	266	74	27	47						
FLORIDA	57	5	52	359	167	192	206	44	162						
ALABAMA	5		5	307	162	145	178	11	167				128	60	68
MISSISSIPPI	6	3	3				49		49						
TEXAS	19	5	14	76	60	16	2852	68	2784	595	518	79			
LOUISANA	30	30		154	129	25	931	52	879	663	608	55			
CALIFORNIA	148	36	112	66	47	19	85	38	47	378	307	71	28	25	3
OREGON	24	5	19	194	52	142							30	11	19
WASHINGTON	33	11	22	646	178	468	77	44	33	5	5		71	41	30
ALASKA															
HAWAII															
TOTAL	657	131	526	3724	1363	2361	6153	543	5610	2303	1794	509	3740	1000	2740
% OF TOTAL TREATED		20			37			9			78			27	

*SEE FOOTNOTES TO TABLE IV.5.7

These tables show industrial water use for the coastal states, not for the coastal counties only, but nearly all wastes discharged into the waters of these states ultimately reach estuarine waters. Only 4000 of the more than 200,000 manufacturing plants in the coastal states account for 97 percent of the total liquid wastes discharged. Of the nearly 22 billion gallons of industrial wastes discharged daily, only 29 percent receive any waste treatment. The Pacific Southwest biophysical region has the greatest percentage of industrial wastes treated, while the North Atlantic biophysical region has the least.

Of the major water use industries shown in Table IV.5.8 the petroleum and coal products industries have the highest percentage of wastes treated and the chemical industries have the least. These five industrial groupings are responsible for 76 percent of the total volume of industrial wastes discharged in the coastal states.

The primary metals and petroleum and coal products industries are centralized in the Middle Atlantic, Gulf, Pacific Southwest, and Pacific Northwest regions, but the other major water use industries are distributed throughout all regions. The kinds of wastes associated with food, paper, and chemical manufactures are therefore universal problems, while the other major industrial waste types concern only particular estuarine environments.

This discussion considers only the volumes of wastes either treated or not treated; it does not consider the level of treatment provided. Some industrial wastes, including those from all major water use industries, require extensive treatment before disposal to the environment. Others do not require anything other than settling and clarification. The precentages of wastes treated, however, do give an idea of relative concern for the environment expressed in action by the industrial and institutional communities.

Desalination operations and the ever-growing nuclear power facilities are new kinds of industry representing potential environmental problems. Salt water conversion plants remove dissolved materials from water to make it fit for municipal consumption and industrial process use. In the case of sea water, where salt concentrations are as high as 33,000 mg/l, the purification of each million gallons of water results in a waste containing almost 300 pounds of impure salts. Nuclear operations present a completely different problem -- that of protecting the environment from exposure to harmful ionizing radiation. Since environmental exposure must be held to a minimum, careful control and monitoring of existing and potential radiological waste sources are essential.

DREDGING AND FILLING

Intensification of use of the estuarine zone has resulted in many

artificial changes being made in its physical structure. Shoreline areas have been filled to create more land area for residential and commercial use; channels have been dredged and maintained to permit safer and better navigation; harbor facilities have been dredged; bridges and causeways have been built. All of these activities have impact on the coastal zone ecosystem, but the activities having the most impact on water quality are dredging and filling. The potential for pollution of the system exists in both filling and dredging; both can introduce foreign materials into the water, destroy aquatic habitat, and alter physical circulation patterns. In the case of dredging, exposed bottom materials, if sufficiently high in organic content, can adversely affect oxygen resources. Disposal of dredged materials often creates another problem -- unless the materials are used for land fill, dredged material creates water quality problems in the disposal area.

The general magnitudes of dredging and filling activities are shown in Tables IV.2.9 and IV.2.10. These generalities hide the slow attrition of estuarine areas by the small bulkheading, filling, and dredging activities associated with statistically small operations such as those associated with improvement of numerous private residences. Probably few such operations create noticeable habitat damage, but the total effect in local areas may be severe over an extended period.

HEATED WASTE DISCHARGES

Waste heat is another type of pollutant that is discharged to the water environment as an expediency. Heat energy can be equally as dangerous to aquatic environment as the other more obvious forms of pollution. The primary source of heat energy is from industrial cooling water effluents. Table IV.5.9 is a summary of the cooling water use by industry for the United States. Power plants are the major users of cooling water in the estuarine zone as shown in Table IV.2.7.

Power generation capacity has approximately doubled each decade during this century. The impact of this growth on the estuarine areas is evidenced by the fact that in 1950 22 percent of the power plants were in the coastal zone; it is anticipated that over 30 percent of the plants will be located there in the late 1970's.

The existing cooling water use and waste heat discharges are summarized in Table IV.2.7. The contrasts among the various regions are related to differences in factors such as the degree of urbanization and industrialization and the availability of hydroelectric power.

TABLE IV.5.9
Industrial Use Of Cooling Water During 1964(1)

Industry	Cooling Water Intake in Billions of Gallons	Percent of Total
Electric Power	40,680	81.3
Primary Metals	3,387	6.8
Chemicals & Allied Products	3,120	6.2
Petroleum & Coal Products	1,212	2.4
Paper & Allied Products	607	1.2
Food & Kindred Products	392	0.8
Machinery	164	0.3
Rubber & Plastics	128	0.3
Transportation Equipment	102	0.2
All Other	273	0.5
TOTAL	50,065	100.00

(1) Data from U. S. Dept. of Commerce, Bureau of the Census, "Census of Manufactures, Industrial Water Use," 1964.

WATERCRAFT OPERATION

Estuarine areas are important highways of commerce; thousands of commercial vessels, foreign and domestic, from ocean liners to barges, traverse the coastal waterways each year. Added to this traffic are many of the 1500 Federal vessels and many of nearly eight million recreational vessels. All of these watercraft carry people and/or cargo, and they are a real or potential pollution source. Just based on an occupancy rate alone, the waterways of this Nation received untreated wastes from vessels equivalent to a city of 500,000. Added to these wastes are the many gallons of oils, bilge water, ballast water, wash water, chemicals, and accidental cargo spills.

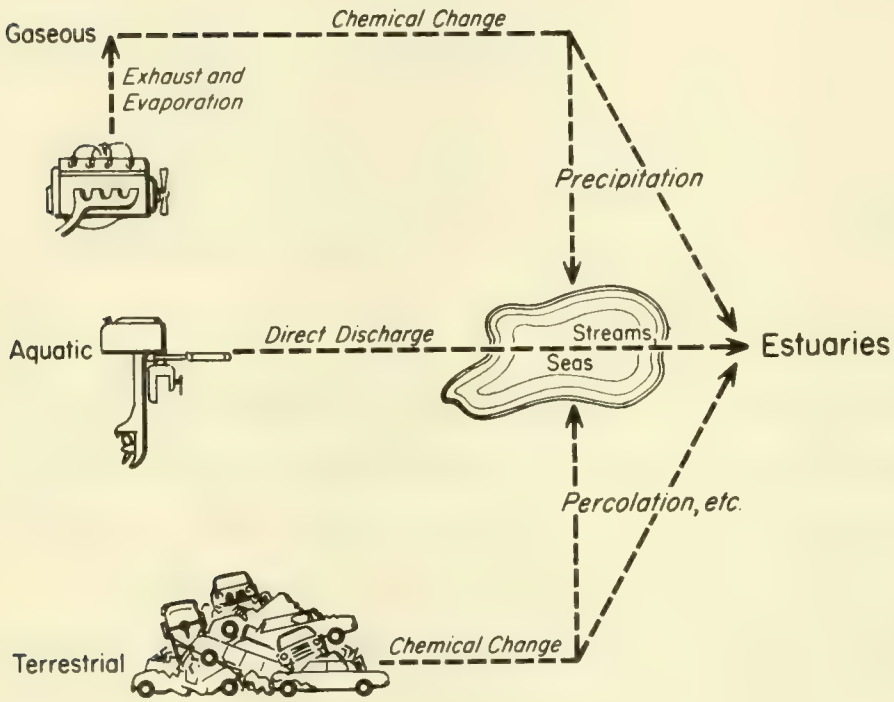
Recreational boat usage creates a somewhat different waste impact from that of commercial traffic. These craft are generally congregated near large population centers, and boat usage is most intense on the weekends when the boat owners have free time. In addition to the human waste and garbage, there are large quantities of unburnt fuel products exhausted from boats, particularly from the two-stroke cycle outboard motors (Figure IV.5.16).

MINERAL EXPLOITATION

Commercial exploitation of the mineral resources in estuarine areas is another potentially significant waste source. Three

Figure IV.5.16

INFLUENCE OF THE USE OF THE
INTERNAL COMBUSTION ENGINE ON
DIFFERENT MEDIA AND ON THE ESTUARIES



types of extractive activities exist in the estuarine zone: (1) sub-bottom mining of sulfur and petroleum, (2) mining of materials such as sand, gravel, and oyster shell from the estuarine bottom, and (3) mineral extraction directly from the water. Each creates a different water-quality problem.

The sub-bottom operations, especially for petroleum, interfere with the aquatic habitat in several ways. In the exploration phase, the use of seismic explosions can be detrimental to the biota in the immediate vicinity. Drilling activities always present the potential threat of a blowout or rupture resulting in a wild well (Figure IV.5.17). Potential problems in the production phase include the possibility of collision or storm damage to the rig and the disposal of the oil well brine. Transportation of oil whether by ship or pipeline poses an additional pollution threat.

In sulphur mining, the Frasch process is generally used; superheated water (325°F.) is pumped into the sulfur formation and molten sulfur is pumped out. The bleedoff waters must be vented from the deposit, and these waters are highly saline with a rather high hydrogen sulfide content (Figure IV.5.18).

Both petroleum and sulfur mining cause a secondary impact due to the shoreline support facilities that accompany their development.

The shoreline development creates problems similar to those discussed under municipal and industrial waste sources.

Mining from the estuary floor causes alteration of the estuarine shape and water circulation characteristics. A secondary effect is the turbidity problem associated with material removal. Mining of sand and gravel from the estuarine floor is universal, while oyster shell dredging in any great quantity is restricted to the Gulf coast. These operations remove part of the estuarine floor with a concomitant destruction of habitat and life. There are also great amounts of suspended and settleable solids frequently released into the water, from which they are redeposited in other places. Phosphate mining, common in North Carolina and Florida, may introduce nutrient phosphates and toxic fluorides into the water.

Extraction of minerals from sea or estuarine water is the third type of mining activity. Minerals extracted include common salt, magnesium oxide, magnesium metal and bromine. Available information indicates that the pollutional impact of the water extraction process is insignificant.

The extent of estuarine mining activities is shown in Table IV.2.8. On a nationwide basis the sub-bottom mining industry is restricted to the Gulf coast of Texas and Louisiana, and the coasts of

California and Alaska. Isolated areas of the other types of mining activity also are shown in the table. The economics of bottom mining and of water extraction compared to the availability of materials from other sources seems to preclude extensive development, except for materials such as sand and gravel.

FRESH WATER INFLOWS

The quality of estuarine areas is dependent not only on direct waste sources but also on the quality of the streams and runoff entering the system. Tributary influent quality is generally a good index of the type and intensity of land use in the surrounding area and upstream from an estuarine system, and it can be a major cause of ecological stress within the system. The complex interactions between fresh and salt water may magnify the effects of pollutants carried into the tidal regime, resulting in quality anomalies completely alien to either fresh or oceanic environments. It is, therefore, imperative to examine the secondary or relatively uncontrollable pollutant source of tributary inflow.

The first item to be considered is the quality of major rivers and streams entering the estuarine area. Many streams are subjected to various uses and abuses in their upstream reaches; by the time they reach the coastal area the full cumulative effects of pollution are exerted. If no regulatory actions were taken,

there probably would be severe quality deterioration throughout the coastal regions of the country. However, the implementation of the water quality standards program through joint Federal-State effort has provided a two-pronged attack on pollution with two levels of regulatory power. Rigid enforcement of this program should result in a steady improvement of the quality of water entering the estuary systems. Table IV.5.10 summarizes the tributary inflow quality from upstream pollution for selected streams entering the estuarine zone. These data are for the first station above tidal influence and show the baseline for management planning. These data may be contrasted with natural river water quality shown in Table IV.1.8.

The second item to consider is the quality of the inflow from land runoff. The pollutional potential of this source is dependent on land use patterns, the rainfall-land runoff relationship, and rainfall intensity. If the land is essentially natural marshland or covered by natural vegetation, runoff does not pose a serious water quality problem. Runoff from agricultural land, however, can be a threat, depending upon the amount of chemical fertilizers and pesticides used and the degree to which the land can be eroded. If the land is urbanized with large paved areas, the runoff can be up to twice as strong as normal domestic sewage because of the oil and other materials carried from the streets and yards (Figure IV.5 .18).

TABLE IV.5.10
Examples of River Water Quality as
Streams Enter the Estuarine Zone

Biophysical Region	River	Typical Observed Water Quality Conditions in Inflowing River
North Atlantic	Merrimack	Bacterial Counts (MPN) above 1,000,000 Dissolved Oxygen (DO) below 50% saturation
Middle Atlantic	Connecticut	MPN above 10,000 DO near saturation
Chesapeake	Potomac	MPN less than 1,000 DO near saturation High turbidity during moderate to high flows
South Atlantic	Savannah	High turbidity during moderate to high flows High natural dissolved organic load, low DO
Caribbean	Canals from Everglades	High natural dissolved organic load, low DO
Gulf of Mexico	Mobile Pascagoula Pearl	MPN above 10,000 MPN above 10,000 High natural dissolved organic load, low DO
Pacific Southwest	Russian	MPN above 5,000
Pacific Northwest	Willamette	MPN above 10,000
Alaska	Yukon	Very high turbidity

Figure IV.1.18 shows the seasonal variation in precipitation for selected coastal stations. This figure shows a rather varied distribution of precipitation throughout the national coastal areas and indicates the seasons when runoff could present problems.

In addition to the pollutants carried in the runoff, the fresh water itself may stress the ecosystem through dilution of the salinity to concentrations lower than those necessary to support some life forms. A case in point is the annual killing of aquatic vegetation in Tampa Bay with the onset of summer rains (Figure IV. 5.19).

Last in runoff consideration is the degree of flow regulation or water resource development upstream from the tidal environment. These upstream impoundments, with the attendant flow regulation, may have both beneficial and detrimental effects. The reservoirs can serve as equalizing basins, providing a rather constant quality of estuarine fresh water inflow. The difference between regulated flows and natural flows however, may cause ecological stress through alteration of the salinity regime or the circulation patterns. Table IV.2.11 is a compilation of flow regulation structures on major estuarine streams.

SECTION 3. EXTENT OF POLLUTION EFFECTS

Environmental damage from human activities manifests itself in changes in water quality and in changes in living communities. Either or both may be caused by any of the kinds of pollution or sources of pollution already discussed.

This section contains separate discussions of degradation of water quality and damage to living communities, but water quality is an integral part of estuarine ecosystems and changes in one are usually reflected in the other. An accurate and thorough analysis of the relationship of pollution to environmental damage must recognize these related factors. The compartmentation of discussion in this section is necessary because water quality studies and ecological studies are rarely conducted simultaneously in the same system. This situation, indeed, is one major existing deficiency in the present approach toward study of the estuarine environment.

DEGRADATION OF WATER QUALITY

One key to the degree of environmental impact is measurement of alteration in water quality. Extensive data have been collected on a few of the estuaries with the most severe problems, and limited information is available on other estuarine systems to outline the emergence, or document the existence, of water quality problems. For the majority of the Nation's estuarine systems, however, there are little or no data to describe existing water quality conditions.

The Northeastern coast of the United States is the most intensively used and the best studied part of the estuarine resource (Figure IV. 5.21). From the Virginia-North Carolina border to the tip of Maine there are 10 coastal states encompassing 15 major estuarine systems and harboring an estimated 1966 population of 45,416,000. Economic development includes a wide variety of commercial, industrial, and governmental activities. Nearly all waste products from this all-encompassing megalopolis are discharged to the estuarine systems. The Chesapeake Bay system, which is one of the largest estuarine complexes in the country, has many areas of water quality impact. The problems in the Potomac River downstream from the Nation's capitol are documented by numerous scientific studies. Pollution in Baltimore Harbor and noxious conditions in the James River have been recorded in detail. (IV-5-10)

The Delaware River and Bay system has been the subject of considerable study for the development of a water quality restoration program. Likewise Boston Harbor, Penobscot Bay, New York Harbor, and Narragansett Bay have been studied in detail to quantify water quality changes and to provide a technical base for developing remedial measures.

The estuarine zones along the coast from North Carolina to southern Florida have not been studied as extensively as those in the Northeast (Figure IV.5.21). Except for Charleston Harbor and the

FIGURE IV.5.21
DISTRIBUTION OF SOME ESTUARIES WITH DEGRADED WATER QUALITY

Savannah River, little concerted effort has been expended in documenting quality changes. The rapid growth of the Miami area is focusing attention on the estuarine waters of southern Florida. The water quality of estuaries of the U.S. Gulf coast is well-defined by field investigation only in several critical problem areas. Tampa Bay, the Mississippi Delta to a lesser extent, the Houston Ship Channel, and parts of Laguna Madre in Texas, have been investigated from the water quality standpoint.

The geomorphology of the Pacific coast is different from that of the Atlantic and Gulf (Figure IV.5.21). The coast, for the most part, is composed of steep rocky bluffs with little or no beach. The estuaries are natural watercourses cut through bluffs and are generally enclosed to some degree by an oceanward sandbar. Because of this rugged coast line, intense urbanization has occured only near the major estuarine systems that form natural harbors. This unique settlement pattern has been reflected in the concentration of estuarine water quality work along the Pacific coast. Systems such as San Diego Bay, San Pedro Bay, Santa Monica Bay, Monterey Bay, San Francisco Bay, and Puget Sound have been studied rather intensely, to either define localized problems, or to reflect long term degradation. Examples are the studies of San Diego Bay that led to the construction of a metro-sewage system with disposal through a deep ocean outfall; investigations of pulp and paper industrial pollution of Puget Sound; studies of the effects on the

Columbia River of radioactive wastes from Hanford, Washington; and the effect of agricultural drainage from the Central Valley of California on San Francisco Bay.

Most of the estuarine zones of Alaska are still unknown quantities from the water quality standpoint (Figure IV.5.24). Pollution has made some impact on isolated areas but the degree of damage is not well-documented. In Hawaii the situation is very similar. Except for Pearl Harbor and Kaneohe Bay there is an extreme paucity of data on the estuarine areas. Guam, Samoa, and the Virgin Islands have not yet felt intense development. The potential of these areas is still to be explored. The scope of existing water quality problems as well as extent of water quality change is not known. Puerto Rico has development concentrated in separated coastal areas. San Juan Harbor has been studied rather extensively and is in poor water quality condition (Figure IV.5.21). Pollution surveys have also been carried out in the estuaries serving other coastal cities such as Ponce, Mayaguez, Arecibo, Fajardo, and Aguadilla which all have sufficient populations to create estuarine pollution problems.

The great variety of kinds of pollution and the different ways in which the many components of waste materials interact with the estuarine environment to damage water quality preclude the choice of a single parameter to define the overall extent of water quality degradation. Damage to water quality can be a direct and obvious thing such as paper and solids from a sewage discharge

(Figure IV.5.25) or as subtle and invisible as the pathogenic organisms which may accompany it.

Table IV.5.11 lists some estuarine systems with severely degraded water quality. While not exhaustive, this list shows the extent of water quality degradation in many of the estuarine systems of the United States, and it gives a general appreciation of the kinds of water quality damage that now exist. The data in this table show only that water quality degradation exists in the estuarine systems listed. In many cases the data available are not sufficient to determine specific sources of the pollution or how to correct it.

DAMAGE TO ESTUARINE ECOSYSTEMS

Pollutional damage to estuarine ecosystems may be sudden and dramatic as fish or other aquatic life forms suddenly dying, or it may be so gradual as not to be noticed for many years.

Fish kills such as those shown in Figure IV.5.26 are readily apparent even to the casual observer; their causes are sometimes not so easy to determine. Industrial wastes appear to be responsible for the majority of fish kills in 1966, the last year for which data are available, with food processing being the most common industrial activity responsible. The estuarine brackish and salt waters, however, had less than one percent of the fish casualties reported; probably one reason is the enormous volumes of waters available for dilution of waste discharges. (IV-5-11)

The effects of physical destruction of habitat are also easy to assess, at least in terms of the immediate damage caused. The more subtle related effects of damage to organisms dependent indirectly on the habitat for food supply are more difficult, sometimes impossible, to determine.

Many studies of different aspects of estuarine biology have been made, but there are only a very few cases in which comprehensive ecological studies have been made of pollutional effects. The available information on the extent of ecological damage is summarized in Table IV.5.12. The information base for this table is exceedingly sparse; most studies were done when there was apparently some damage or other kind of ecological problem. Therefore, it is not possible to say whether 38 percent of the Nation's estuarine systems are undamaged or merely present no identifiable problems at this time (IV-5-10).

The estuarine systems of the Middle Atlantic biophysical region have suffered the most damage; 83 percent exhibit some ecological damage, but only in a few cases is the extent known in any quantifiable sense. The Chesapeake Bay and Gulf of Mexico regions have the largest numbers of heavily damaged systems, probably because of the intensity of use of the estuarine systems in these regions. Forty percent of the estuaries of the Pacific Southwest region are heavily damaged; this reflects the intensive development of the relatively few estuarine systems of this region.

TABLE IV.5.11
SOME ESTUARINE SYSTEMS WITH DEGRADED WATER QUALITY (1)

Biophysical Region	Major Source of Water Quality Degradation (2)		
	Low Dissolved Oxygen (under 50% sat.)	Bacterial Contamination (over 1000 MPN Total)	Other
North Atlantic			
Penobscot Bay	X	X	Toxic materials
Salem, Marblehead, Nahant Bays	X	X	
Boston Harbor	X	X	
Middle Atlantic			
Providence River	X	X	
Connecticut River		X	
Port Chester - Stamford	X	X	
Moriches Bay		X	Excess nutrients
New York Harbor	X	X	
Raritan Bay		X	
Cape May Inlet	X		
Delaware River	X	X	
Chesapeake Bay			
James River	X		
Potomac River	X	X	
Baltimore Harbor	X	X	
Choptank River	X	X	
South Atlantic			
Cooper River (Charleston, S.C.)	X		Sedimentation
Savannah River	X	X	
Altamaha River		X	
St. Johns River	X	X	
Caribbean			
Upper Biscayne Bay	X	X	
San Juan Harbor	X	X	

TABLE IV.5.11 (Continued)

Biophysical Region	Major Source of Water Quality Degradation (2)		
	Low Dissolved Oxygen (under 50% sat.)	Bacterial Contamination (over 1000 MPN Total)	Other
Gulf of Mexico			
Tampa Bay	X	X	
St. Joseph Bay	X	X	
Pensacola Bay	X		
Mobile Bay	X	X	
Mississippi River		X	
Galveston Bay	X	X	
Matagorda Bay		X	
Corpus Christi Bay		X	
Laguna Madre	X		
Pacific Southwest			
San Francisco Bay		X	
Monterey Harbor		X	
Los Angeles Harbor	X	X	
San Diego Bay		X	
Pacific Northwest			
Columbia River		X	
Elliot-Bellingham Bays(Puget Sound)	X		Toxic materials
Alaska			
Silver Bay	X		
Pacific Islands			
Hilo Harbor		X	Sugar cane debris

(1) Inclusion in this table means only that there are zones within this system where water quality is degraded in the manner shown. It does not mean that the entire estuarine system is of degraded quality. The evaluations presented are based on water quality data in the National Estuarine Inventory, and on additional reported data.

(2) The most obvious and severe type or types of degradation are indicated; other forms of pollution may be present.

FIGURE IV.5.26 FISH KILL

COURTESY LOUISIANA WILD LIFE & FISHERIES COMM. PHOTO BY ROBERT N. DENNIE.

TABLE IV.5.12
Ecological Damage in the Estuarine Zone (1)

Biophysical Region	Extent of Damage				No Damage or No Information		Total
	Heavy		Moderate				
	Number	Percent	Number	Percent	Number	Percent	
North Atlantic	5	8	34	56	22	36	61
Middle Atlantic	23	21	68	62	19	17	110
Chesapeake Bay	40	25	61	39	57	36	158
South Atlantic	11	14	35	44	34	42	80
Caribbean	1	4	18	72	6	24	25
Gulf of Mexico	65	30	102	48	47	22	214
Pacific Southwest	22	40	13	24	20	36	55
Pacific Northwest	6	10	24	40	30	50	60
Alaska	2	2	5	6	79	92	86
Pacific Islands	4	12	5	16	23	72	32
Total	179	20	365	42	337	38	881

(1) Data from Reference IV.5.10

SECTION 4. EXAMPLES OF ESTUARINE SYSTEMS DAMAGED BY POLLUTION

Even though water quality damage and ecological damage are difficult to quantify in terms of exactly how much damage has been done and what was its cause, many estuarine systems have felt the deleterious impact of human exploitation. Examples showing the impact of one particular source of pollution or of one kind of pollutant are rare, because use of the estuarine resource is seldom confined to a single type of activity. The estuarine systems discussed here were chosen because one particular kind of pollutional situation or effect seems to dominate the environment; but, nevertheless many other conditions contribute to the total environmental damage in each case.

MUNICIPAL WASTES

Raritan Bay

Raritan Bay between New York and New Jersey is a prime example of a polluted estuary surrounded by an intensively developed area (Figure IV.5.27). The Raritan system, which is composed of the Bay itself, the Raritan River, the Arthur Kill, and the Narrows receives approximately 1,500,000,000 gallons of wastes per day which contain over 1,300,000 pounds of BOD. Although 75 percent of the waste volume is from industry, the major impact on the estuary is from the nutrient and bacteriological content of the municipal sewage. The densities of bacteriological indicator organisms along the shorelines of the Bay and in the confluences of the tributary systems indicate gross

contamination with human wastes, and the nutrient materials contributed by municipal sewage systems have been sufficient to upset the ecological balance in the system.

In some portions of Arthur Kill and the Raritan River dissolved oxygen values reach zero in summer conditions, and the western part of Raritan Bay also has depleted dissolved oxygen. High photosynthetic production by algae counteract these effects in the larger part of the Bay itself.

Coliform bacteria counts are high throughout much of the Bay and have forced the closing of some public bathing beaches; dye tracer studies showed that unchlorinated human waste discharges from the Upper Bay (New York Harbor) reached beaches on Staten Island within six hours. In 1961 an outbreak of infectious hepatitis was traced to raw shellfish taken from Raritan Bay in the areas within influence of these human wastes.

The investigations of the Raritan system have been in progress for a sufficient length of time to document both the polluted conditions and the beginning of recovery due to the construction of pollution abatement facilities. Bacterial contamination still exists but the biological community is recovering to form a more diversified and stable aquatic population (IV-5-8).

Potomac River, D. C., Md., Va.

The head of the Potomac estuary near Washington, D. C., is severely

polluted by the municipal wastes of the Washington metropolitan area. Nowhere is there such a clear example of the effects of massive municipal waste discharges on an estuary. During the low flow periods of the warm summer months, dissolved oxygen levels approach zero in some reaches, being kept from total depletion by heavy production from large algae growths. The effects of these waste discharges are measurable along twenty miles of the river (IV-5-9).

James River, Va.

Another example of sewage wastes in an estuarine system is the James River in Virginia (Figure IV.5.28). The James River is the most southerly major tributary of the Chesapeake Bay. It is approximately 400 miles in length and varies in width from five miles at the mouth to less than 0.1 mile in its upper extremities. The River is tidal from its mouth to the city of Richmond, a distance of 90 nautical miles. The freshwater - saltwater interface migrates between river mile 24 and 60, depending on tide and river flow conditions.

Richmond, Va., is the major waste source on the upper James. Wastes from this city have caused an over enrichment of the upper river section which has resulted in nuisance growths of algae typical of polluted water. The saline sections of the River have not reflected hyper-fertilization and are in the transitional stages.

However, brief flareups of nuisance biological growths have occurred and it appears that these nuisance conditions will remain for longer periods of time until a noxious stability is reached (IV-5-10).

Upper Biscayne Bay, Fla.

This is one of the many bays on the Florida coast in which the shallow depths allow light penetration sufficient for the growth of submerged vegetation (such as grasses) and algae. Among the impacts of raw sewage discharges into such systems are the limitation of light penetration due to suspended solids and the settling of organic material to the bottom. Both of these impacts affect the submerged vegetation and algae.

Upper Biscayne Bay is located between Miami and Miami Beach. It is non-uniform in width (2 to 4 nautical miles) and is approximately 6 nautical miles in length. The Miami River enters the southwest portion of the bay (Figure IV.5.29). The total number of sewage outfalls entering Upper Biscayne Bay was 70. The Miami River, carrying the sewage from 29 outfalls, was the major pollutant source. It is estimated that 30 to 50 mgd raw sewage flows into the bay.

Kinds of fixed vegetation divided the bay into two major zones. Along the Miami shoreline was a zone of red algae, which can survive in low light intensities, and most of the surrounding bay was a zone

of grasses and other vegetation requiring much sunlight. No life was found at locations above the Miami River mouth in areas near sewage outfalls, and there was a zone in mid-bay containing no fixed vegetation.

The softest sediments were found along the Miami shoreline just north of the Miami River mouth. Soft sediments also occurred in mid-bay with harder sediments along the shores of Miami and Miami Beach where the currents are stronger.

The oxygen consumption of the sediments was highest in the softest sediments just north of the Miami River mouth, in the northwestern portion of the bay, and in the deep water south of the Miami River mouth. These zones were relatively deep, had poor bottom circulation and were zones of major deposition of organic-rich material.

Both harmful and fertilizing effects were observed in Biscayne Bay. The harmful effects were indicated by the absence of life. These areas were within 200 yearss of sewage outfalls, were greater than average depth and had soft, sticky mud with high amounts of oxidizable organic matter. The fertilizing effects were most pronounced in areas 200 - 600 yards from outfalls in shallow water with good tidal circulation in firm sandy mud. Species associations within definite communities were found to be indicative of both the harmful and fertilizing effects (IV-5-10).

INDUSTRIAL WASTES

Los Angeles Harbor, Calif.

The Los Angeles Harbor portion of San Pedro Bay, Calif., provides an example of an estuarine system receiving oil refinery wastes. These wastes were discharged into enclosed basins or slips which had very limited tidal circulation and flushing. The effects on the receiving system were reflected in progressive studies of the benthic biological community. Initial investigations showed the bottom to be composed of black oily material with the odor of hydrogen sulfide, a characteristic of anaerobic conditions. The receiving area was subsequently bridged, and a diverse population of bottom organisms began to populate the area. The continuous discharge of the refinery waste, however, eliminated the biota after a relatively short time. This example demonstrates the ability to recover if proper management techniques are utilized (IV-5-10).

Silver Bay, Alaska

Another example of the water quality changes caused by industrial wastes is the Silver Bay system of Alaska. A paper pulp mill located on the Bay discharges sulfite waste liquor to the waste surface. Water quality sampling of the bay demonstrated extensive degradation of the surface water stratum as indicated by depressed dissolved oxygen concentrations, changes in pH (hydrogen ion concentration), and increase in turbidity. Vertical profiles of

these water quality parameters indicated that the waste materials remained on or near the surface in a low-density layer. The concentrations of the sulfite waste liquor were sufficient to be toxic to many of the natural food chain organisms and to cause abnormalities to oyster larvae and fish eggs (IV-5-10).

Honokaa, Hawaii

Located on the north coast of the island of Hawaii (largest of the Hawaiian Islands) is a complex of six sugarcane processing plants. These mills are remotely situated along an inaccessible shoreline characterized by steep cliffs one hundred to two hundred feet high. The alongshore currents push the wastes long distances along the shore and then out into the ocean.

The main effects of the sugarcane wastes have been the shading of coral by the highly turbid waters, the occurrence of high phosphorus and coliform concentrations, and the lowering of fish diversity and productivity. The slope of the ocean floor nearshore is steep and great depths are reached in a short distance. Thus, the mixing and dilution capacity of the deep water minimizes the effects within a shore distance offshore, while some wastes drift along shore with the currents.

With the mixing and current structure of the steeply sloping ocean bottom, the effects of the sugarcane mill wastes on the hydrography

of the area is negligible. There is no significant difference in the oxygen concentration, temperature or salinity in the outfall area. The color of the waste from the sugar mill is that of the soil carried with the cane from the fields (the common mode of harvesting sugarcane is with the aid of a bulldozer and considerable soil is scraped up with the cane and hauled to the processing mill). The soil is a bright red-brown color, and this color, plus the turbidity produced by washing the cane before crushing, is discharged into the ocean producing a vivid contrast to the surrounding blue water. The alongshore currents carry this turbidity great distances along the shore instead of allowing it to be diluted further out at sea.

One of the more distinguishing characteristics of a tropical coast is the large quantity of coral. In the sugar mill waste disposal area at Honokaa, the coral has been completely covered with sludge (composed mainly of bagasse, and settleable solids) within a radius of one-quarter mile from the outfall. For the next quarter mile on either side of the sludge deposit, the coral coverage has been reduced to about 10 percent total coverage. For the third quarter mile down current from the outfall, the coral coverage is between 10 and 55 percent. The coral coverage on the down current side of the outfall does not reach normal density until about three-fourth mile from the outfall, where coverage is about 55 percent (considered normal for comparable areas). There is little

doubt that the reduced coral density is a result of the increased turbidity, since coral relies upon light penetration for its formation and maintenance.

At many sugarcane mills, the normal procedure is to combine human sewage with the sugarcane wastes. This practice results in very high concentrations of coliform bacteria, because the bacteria in the warm sugar-laden waste multiply rapidly. At the outfall of the Honokaa mill, the coliform count was 100,000 per 100 milliliters (ml). The coliform concentration was still as high as 1000 per 100 ml at a distance of one mile down current from the outfall.

Many tropical fish are dependent upon the coral reef structure for protection from predators and on the organisms symbiont with coral reefs for food. Since the coral in the Honokaa sugar mill outfall area was destroyed, it is reasonable to expect that the fish population also deteriorated. The diversity of fishes in the outfall area decreased to 16, as compared to a normal 60 found two miles away. The biomass of fish was also reduced near the waste disposal area; 160 pounds per acre (lb/acre) during the sugarcane grinding season, compared to 600 lb/acre two miles away (IV-5-10).

DREDGING AND FILLING OPERATIONS

Laguna Madre

One good example of water quality changes from dredging and filling operations is South Bay of the Laguna Madre system in Texas (Figure IV.5.30). The dredging and redredging of the Brownsville ship channel resulted in almost complete enclosure of the South Bay from Laguna Madre. Settlement of suspended sediment has caused a 60 percent reduction in depth in South Bay and has changed the bottom characteristics from desirable vegetative habitat to soft mud. The water circulation has been reduced and salinities have increased, and composition of the biological community has been altered in terms of number and density of species (IV-5-10).

UNDERSEAS MINING OPERATIONS

Petroleum production in the estuarine areas of the Nation is now big business. The pollution potential of this extraction industry is staggering to the imagination. The damage that could occur to fish, wildlife recreational utilization, and shoreline structures from well blows and broken pipelines is immense. The oil industry is well aware of this hazard, and since 1955 there have been only eight such incidents. The primary pollutional effects of these occurrences to date have been high mortality of waterfowl in the area of the oil slick and nuisance contamination as a result of oil washing onto shoreline areas.

The 1956 blowout in Louisiana was accompanied by a rather severe fire. The crude oil spill was out of control for approximately two weeks. Ecological studies for two years after the spill did not demonstrate any significant damage to the biological community in the spill area as contrasted to control areas outside the sphere of influence (IV-5-10).

The well publicized blowout in Santa Barbara is another example of water quality impact from mining operations. As a result of this accident, in January 1969, large numbers of waterfowl were killed by contact with the oil and some prime recreational beaches were contaminated. The total extent of damages to the ecosystem have not been assessed and will await the findings of extensive studies.

HEATED EFFLUENTS

As population centers develop in the estuarine zones of the country, demand for electric power increases. This growing power demand is usually met through the construction of either fossil-fueled or nuclear-powered thermo-electric plants. Since these plants are only between 20 and 40 percent efficient in the conversion of thermal energy to electric energy, tremendous quantities of heat must be wasted to the environment. There are many examples of water quality changes due to thermal discharges.

The Chalk Point nuclear power plant on the Patuxent River estuary in Maryland has altered the temperature regime considerably. The Contra Costa and Pittsburg, Calif., plants have created a new temperature environment on the San Joaquin River in the delta area of San Francisco Bay. Cooling water from Turkey Point plant in Biscayne Bay, Fla., and the Morrow Bay plant in southern California has created thermal structures that may be as high as 10°F above ambient temperature.

These examples represent only a few of the many thermal discharges from power plants. Other industrial manufacturing processes utilize considerable quantities of cooling water and may cause the same type of environmental changes in addition to generating wastes.

LAND USE AND RUNOFF

Indiscriminate use of land areas contiguous to estuaries has resulted in severe water quality problems (IV-5-10). There are many documented cases of pollution from land runoff. One of the most serious is the tremendous impact created by the widespread application of insecticides to control fire ants in the southeast. The spraying programs were apparently initiated without consideration of the potential unsought consequences, and the heavy toll of birds, fish, and other mammals was phenomenal.

Runoff from such uninhabited areas is not the only culprit. In 1968, Endrin released in storm sewers found its way into Northeast

Cape Fear River in North Carolina. Thousands of fish, including many anadromous species, were killed (IV-5-10).

Studies of the pollutional effect of storm runoff in Boston Harbor have shown significant increases in deoxygenating substances, as well as bacterial indicator organisms. Control of storm runoff is extremely costly, but it is a very real part of pollution control.

Runoff from phosphate mining areas in North Carolina and Florida has added large quantities of nutrients to estuarine systems. The phosphate material combined with sewage and other nutrient sources forms a unique, enriched aquatic environment with a real nuisance potential.

STREAM FLOW REGULATION

Stream flow regulation structures have been built on many of the rivers directly tributary to estuarine systems. For the most part these structures have had a beneficial influence on estuarine water quality. The regulated stream flow provides a more uniform source of fresh water with fairly constant quality which allows the estuarine system to reach a dynamic equilibrium. In addition, the reservoirs act as settling basins, reducing the sediment load in the estuaries. In a few cases the flow regulation has so restricted the fresh water inflow that the estuarine salinity structure has changed.

Water quality changes resulting from the construction of flow regulation structures are demonstrated in the following examples:

(1) In the San Francisco Delta, upstream salinity intrusion is controlled by releases from reservoirs on the Sacramento River. Conversely, regulation of flow in the San Joaquin River is partially responsible for recurring quality problems in the Stockton area of the Delta; and

(2) The construction of Santee-Cooper complex in South Carolina resulted in the diversion of the combined flows of the Santee and Cooper Rivers into Charleston Harbor. This flow regulation created a complex sedimentation problem and changed the vertical salinity in Charleston Harbor.

Upstream Water Quality

Among the more significant considerations in the quality of any estuarine environment is the quality of the inflowing stream. If the freshwater inflow is polluted, the impact may be felt throughout the entire system. A good example of this phenomena is the St. Johns River in Florida. The St. Johns carries large quantities of municipal and industrial wastes into the tidal area (IV-5-10).

The poor quality is further degraded by additional waste discharges from the urbanized area near the estuary mouth. The total

impact is a grossly polluted estuarine system which also affects the portions of the coastal beaches around the mouth.

Wastes from Watercraft

Commercial and recreational boating on estuarine waters is the most visible and picturesque water use. These watercraft, however, constitute a continual threat to the quality of the estuarine environment. An ocean liner with 1000 passengers is a small floating city and accordingly has wastes that must be discharged. A sailboat represents only one of the millions of pleasure craft in this country and when large numbers of the craft are congregated in a small area, a significant waste source is created.

The pollutants discharged include sewage, oils, chemicals, and other wastes, not infrequently involving accidental spills of valuable and/or dangerous cargoes. The uncertainty of discharges as to number, time, place, and frequency adds to the hazard and control problem. Recent activities by both Federal and State government agencies to combat pollution from vessels should rectify this situation by requiring waste treatment devices (IV-5-11).

SECTION 5. CONCLUSION

The complex nature of pollution in the estuarine zone prevents the separation of sources of pollution, kinds of pollution, and types of environmental damage into neat compartments of cause and effect. All human activities in the estuarine zone can damage the environment, and most of them do.

Wherever people live, work, and play in the estuarine zone their social and economic activities place stresses on the biophysical environment. These stresses frequently result in degradation of that environment, perhaps not immediately or even in a few years, but nonetheless certain in its devastating final impact.

Environmental degradation is not a necessary feature of man's association with the estuarine zone. The examples discussed in Chapter 2 of the results of community effort as in San Diego Bay, and of industrial responsibility as in the management of Avery Island, show that pollution and socioeconomic activity need not be synonomous. The massive planning effort just completed in San Francisco Bay shows that even the most complex use and pollution problems can be resolved with careful, determined study.

Pollution in the estuarine zone has been largely a matter of a lack of concern and a lack of knowledge combined with nebulous management authority and responsibility. Continuing use of the estuarine zone for all human needs and desires is a fact of man's

existence. Accommodating all uses while preserving the environment is a matter of knowledge, concern, and determination.

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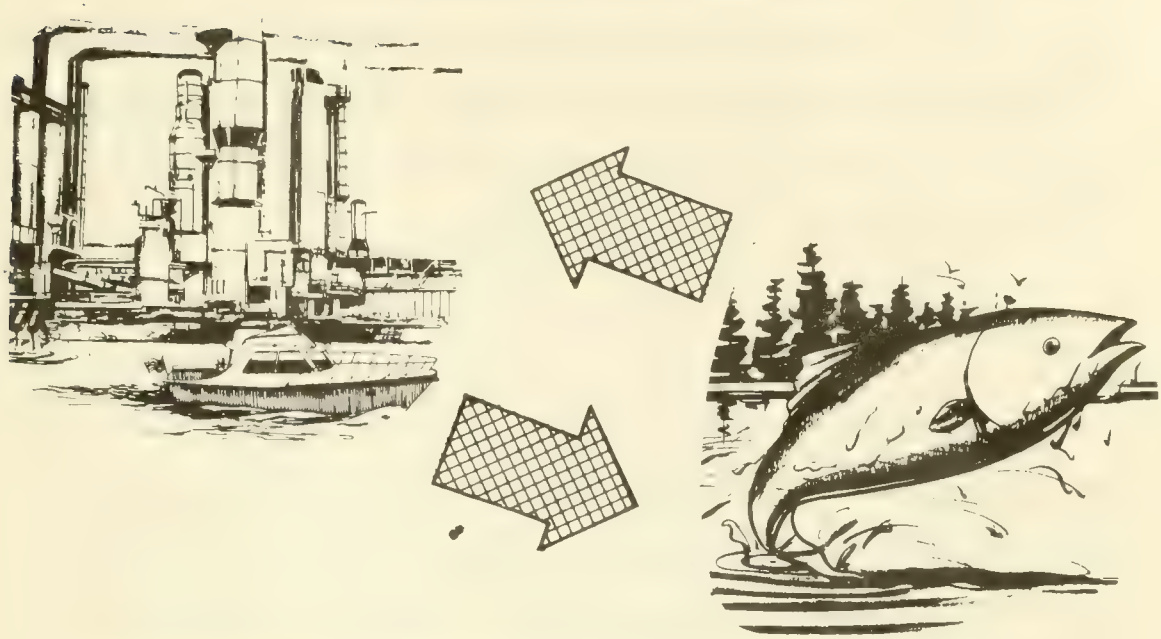
Chapter 6

USE CONFLICTS AND DAMAGES



The consequence of damage to the biophysical environment is loss of use either immediately or at some time in the future. Loss of use, however, may also be associated with the appropriation of part of the estuarine resource for one exclusive use even when no damage to the environment itself occurs.

Institutional management copes with the problems of responsibility and authority in achieving maximum multiple use of the estuarine resource. Within this comprehensive framework technical management must resolve the problems surrounding conflicts of use, competition for the resources of the estuarine zone, and environmental damage. The primary objective of technical management is to achieve the best possible combination of uses to serve the needs of society while protecting, preserving, and enhancing the biophysical environment for the continuing benefit of present and future generations.

This chapter deals with the problems of use conflicts and damages and relates these to probable trends in estuarine ecology as the basis for guidelines within which technical management can function effectively to achieve its primary objective.

SECTION 1. THE NATURE OF USE CONFLICTS

The uses of estuarine zone grew and changed in consonance with population growth and industrial development. Not until recent years was a concerted attempt made to understand and resolve the conflicts that arose in the competition to use and exploit these land and water resources. During the past three hundred years of growth and industrial expansion with its emphasis on economic growth and direct monetary gain, large parts of the estuarine zone were pre-empted or usurped to serve the individual needs of commercial enterprises. The net result has been less a conflict in existing uses than an exclusion of some uses.

Nearly all estuarine uses involve both land and water, either directly or indirectly. For example, the construction of a manufacturing plant on the shore of an estuarine system may not involve any direct use of the water (even for waste disposal), yet it limits access by its occupation of the shoreline and so may interfere with other uses. Conversely, the disposal of liquid waste into the water may make the shoreline unusable for recreation as well as making the water itself unsafe.

The impact of one estuarine use on another may be either "prohibitive" or "restrictive" depending on the kind of use and sometimes on the manner in which it is carried out.

PROHIBITIVE IMPACTS

These involve permanent changes in the environment and thereby prohibit all uses unable to cope with such changes. The geographical range of such impacts may be from the limited area in which they occur to an entire estuarine system, depending on the nature and size of the change. The impact may be temporary, if it is possible to return the environment to its original form, or it may be permanent.

Any use or activity requiring physical modification of the shoreline, marshes, or bottom of an estuarine system may have a prohibitive impact. Modification of water circulation also tends to be prohibitive when it has any conflicting impact.

Navigation Channel Dredging

This is probably the most widespread and constant permanent modifying activity in the estuarine system. It is carried out solely to maintain and improve navigation needed for commercial and recreational purposes and for national defense. Dredged navigation channels must be kept clear for navigational purposes, and the bottom is constantly being removed. Both of these

conditions preclude the large-scale use of such areas for purposes other than navigation.

The disposal of dredging spoil may also be a prhoibitive estuarine use when it is deposited in other parts of the system or on adjacent marshes or land. The destruction of habitat which can result from such disposal will at a minimum remove the areas used for productive participation in the estuarine ecosystem.

The prohibitive impact of navigation dredging may, however, affect an entire system. particularly where a major channel realignment or channel deepening occurs. The prohibitive impact of such modification may not be in direct destruction of habitat, but may result from a change in water circulation patterns.

For example, a change in current structure associated with channel deepening in the James River prevented the upstream transport of oyster spat to the beds where they normally settled and grew to edible size (IV-6-1).

Such prohibitive use impacts are not always associated with the dredging of navigation channels; in fact, such activities can enhance the environment by improving water circulation and creating new habitat. When there is an impact, however, it is prohibitive in that it permanently excludes other uses while the channel exists.

Land Fills

The operations of dredging and filling associated with the creation of dry land from marshes and estuarine shallows may have severe prohibitive impact on other estuarine activies. The massive areas filled for large residential and industrial developments destroy much of the environment directly; and, in many cases, the areas involved are large enough to make a significant impact on water circulation and even on the total volume of water in an estuarine system.

Large fills, such as those made for airports, also limit access to estuarine waters, thereby permanently limiting the recreational potential of such areas.

Solid Waste Disposal

The use of undeveloped estuarine shoreline areas for final disposal of garbage and other solid waste materials is not only prohibitive in the same sense as other filling operations, but also the drainage and runoff from such sites can have a severe and continuing impact on water quality.

Although reliable figures showing the impact of solid wastes on the estuarine environment are lacking, a situation from the San Francisco Bay Area is instructive: "In some instances, Bay water has leaked into old dumpsites; when the tide goes out, black sludge is carried into

the water and hydrogen sulfide gas escapes into the air. In every dump, even including those where no garbage is buried, an increase in temperature plus an amount of decay produces hydrogen sulfide." (IV-6-2). In combination with salt water this produces a vile odor that produces numerous complaints from residents near such dumps. In short, the cost of cheap dumping of solid refuse despoils not only the land surface to the west and the air for miles, but ultimately the water quality of the Bay itself.

Such use has prohibitive impact because of the uncontrollable nature and permanent damage caused by such activities.

Bridges, Jetties, Dikes, Breakwaters, Causeways

The prohibitive impact of such structures, when it occurs, is usually far more gradual than the impact of large land fills. The group of structures discussed here are either deliberately placed in an estuary to control water movement or else cross the system to carry land transportation. In either case they are long narrow structures which affect water movement patterns. Their effects may be beneficial to the environment or they may be the reverse.

The construction of a highway through the coastal area of Louisiana and Mississippi effectively separated the inland areas of the coastal marshes from the outer marsh areas, completely altering the circulation patterns of the entire marsh system. The result has

been saltwater intrusion into the outer marsh system (in the absence of the freshwater inflow from inland sources now prevented by the highway), with the subsequent results of soil alteration and eventual alteration of the marsh vegetation (IV-6-3).

Such alterations may permanently change ecosystems and therefore exclude the estuarine uses which depend on them. Commercial fishing and sports fishing are particularly impacted by such changes.

Shoreline Development

Estuarine shorelines are extremely valuable for both commercial and residential development. The shorelines of large cities are extensively built up, primarily for navigation access and other commercial development, but with considerable areas of shoreline drives and residential developments. Nearly all of such kinds of development extend up to, and sometimes beyond, the natural shoreline and terminate in bulkheads, docks, or other permanent structures.

The individual impact of such development is probably minimal except in extremely confined areas, but the total effect of the shoreline development of a large city can be to drastically and irretrievably change the natural environment, even to the extent of damaging the uses for which the changes were made.

Reduced currents and changes in water circulation may result in increasing rates of dedimentation and added expense for channel maintenance.

Changes in circulation associated with both spoil disposal and manufactured residential islands in parts of Tampa Bay were followed by changes in sedimentation patterns and an apparent decrease in productivity in some areas (IV-6-4).

Mining

The taking of materials from the estuarine bottom immediately destroys the local habitat and the movement and settling of suspended material may extend the damage to other areas. Sand and gravel dredging are universal activities in the estuarine zone; oyster shell dredging exists in several areas along the Gulf and Atlantic coasts.

Phosphate sand or rock mining in estuarine systems may raise the concentration of phosphorus in the water and change the ecological balance of the entire estuarine environment, as well as directly killing fish and other aquatic organisms.

Mining operations exploit a non-renewable resource, and even after mining operations have ceased, the hole in the bottom of the estuary may affect water circulation throughout the estuarine system.

Flow Regulation

The ecological balance of an estuarine system is the result of interaction of the dominating environmental factors discussed in Part IV., Chapter 1. Among these factors are the amount and annual distribution of fresh water inflow. Upstream flow regulation may have many

beneficial effects, but radical changes in the annual river flow pattern may cause drastic changes in both water circulation and in ecological balance.

The harbor of Charleston, South Carolina, was a deepwater port with freshwater inflow from only coastal drainage until the flow of the Santee River, averaging 15,000 cubic feet per second, was diverted into it. This caused salinity stratification to set in and sedimentation became a severe problem. Dredging requirements grew from 120,000 cubic yards per year to over 7,000,000 cubic yards per year and many of the docks had to be abandoned because adequate depths could not be maintained. The prohibitive dredging costs have resulted in a Corps of Engineers proposal to redivert the Santee River away from Charleston Harbor. (see case study p. IV-484)

Some of the more productive oystering areas in the Potomac River are in a reach where high springtime river flows reduce salinities enough to kill the oyster drills (a predator) but not kill the oysters. Flow regulation to reduce the high spring flows would probably change this relationship.

RESTRICTIVE IMPACTS

Some estuarine uses may restrict use for other purposes but do not automatically exclude other uses. These are those activities which do not require a permanent modification of the estuarine system; they generally include those uses directly involved with the estuarine waters

and other renewable resources.

Restrictive impacts may involve damage to water quality, living organisms, or aesthetic quality; such impacts may also result from the exclusive appropriation of space. The key feature of uses which cause restrictive impacts is that they may, with proper management, be carried out simultaneously with other uses.

Liquid Waste Disposal

Although not generally regarded as a beneficial use, the discharge of liquid wastes to estuarine waters is and is likely to continue to be one of the major universal uses of the estuarine zone. The present discussion considers liquid waste disposal as one of many uses of the estuarine environment which has the potential of conflicting with other uses but which will probably have to be accomodated within the overall use patterns of nearly all estuarine environments.

The major restrictive impacts of liquid wastes arise from the disposal of untreated or inadequately treated wastes in massive quantity to estuarine waters. The discussion in Part IV, Chapter 5, pointed out the various pollutional effects different types of municipal and industrial wastes can have, and presented some typical examples of pollutional effects. Six types of impacts tend to restrict other uses:

1. Floating or settleable materials make the system unpleasant or destroy bottom-living organisms.
2. Decomposable organic materials deplete oxygen necessary for aquatic life and may cause nuisance conditions.
3. Toxic materials destroy living organisms by killing them directly, damaging their reproductive ability, or poisoning their food supply.
4. Nutrient materials cause over-production of some ecosystem components causing adverse effects on others
5. Pathogens create public health hazards.
6. Heated waste discharges reduce available oxygen and cause other adverse effects on the ecosystem.

These kinds of impacts adversely affect the living resources or aesthetic quality or create a public health hazard. The damage to living resources can be catastrophic when waste discharges are large in volume, strong in concentration, or prolonged in time. Such discharges are restrictive rather than prohibitive, however, in that removal or significant reduction of the waste discharge will permit a healthful ecosystem to slowly reestablish itself with consequent full reestablishment of the formerly restricted uses. San Diego Bay, discussed earlier, is an excellent example of this.

Commercial fishing, recreation, and water supply are the major uses restricted by pollution from liquid waste discharges.

Commercial Fishing

Fisheries may be affected adversely either by damage to fishery resources or by imposing a public health hazard which makes the harvestable product unsafe. The fishery resource, whether finfish or shellfish, may be damaged by the direct killing of marketable species, by the killing or poisoning of a necessary food supply, or by damage to the reproductive capability of any part of the food chain. Any or all of these may occur, depending on the waste discharge characteristics.

Oysters, mussels, and clams are susceptible to these damages; in addition, their meats may be made unsafe for human consumption by the suspected presence of wastes containing pathogenic organics or toxic materials which such animals tend to concentrate in their tissues. It is important to recognize that the conflict in use arises from the inability to market the shellfish product because of necessary public health considerations, and that there may be no damage at all to the shellfish habitat, particularly if the waste is treated domestic sewage, which contains excellent nutrients for shellfish.

Recreation

Liquid wastes may have restrictive impacts on both body contact and non-contact forms of recreation. The invisible dangers of

waterborne pathogenic organisms are as important in restricting recreational use as the floating scum and oil which damage aesthetic quality and cause people to go elsewhere.

Recreational use is never entirely eliminated. Even around the most polluted estuarine areas can be found an occasional fisherman or boating enthusiast. The people who cannot go elsewhere will use their local estuarine zone in whatever fashion is possible, even if there is a public health danger or the environment is unpleasing. The dangers inherent in such use fall primarily on children, who tend to play in any available puddle, not caring whether it is the local swimming hole or New York Harbor.

Water Supply

The use of estuarine waters for municipal and industrial process water supplies is not extensive because its primarily brackish quality makes it difficult to threat adequately and economically. Estuarine waters are used extensively for industrial cooling water use, and waters with suspended solids, high acid or alkali concentrations, or high nutrient concentrations are difficult to use. Such waters clog screens, corrode pipes, or develop slimes which require added maintenance expense.

With increasing population and industrial growth in many coastal areas and increasing demands for potable and industrial process

water, the use of fresh estuarine waters for water supplies may become an important estuarine water use. Fresh waters in the estuarine zone occur near where the rivers reach sea level, and it is here at the natural head of navigation that many of the large ports are located and discharge their wastes.

Commercial Fishing

Some kinds of commercial fishing require the use of trawls or the setting of traps or nets that must be left for some time. The use of such devices restricts other uses while the devices are in place, but there is no permanent appropriation of estuarine waters or space. The major conflict is with recreation in that recreational boating must be excluded from areas where fishing gear is near the surface.

Shellfishing is restrictive in the sense that commercial oyster and clam beds require the waters above them to be of far better quality than is required for safe body contact. This has been a significant impact up to the present only in that waste treatment requirements of some municipal and industrial wastes have had to be set higher than would otherwise be necessary. With increasing numbers of watercraft in estuarine waters the potential additional human wastes from these boats may require restriction of some waters to recreational traffic in order to protect shellfish beds.

SECTION 2. EXAMPLES OF USE DAMAGE

Where there is conflict, the scene is set for trade-off, i.e., a willing substitution of one activity for another. The scene is equally set for uncompensated damage where one user group precludes the activities of a second unrelated user group but does not reimburse them for damage. Several examples will demonstrate the types of damages and the difficulties in quantifying them. Essentially, the damage is the value of the use which is precluded or foregone, and the same type of use valuation problems as discussed earlier are applicable.

Actual documented examples of use damages are difficult to find. One major reason is the basic fact that has permeated much of the discussion of economic and social values: Many estuarine values are not quantifiable. While damages to a commercial enterprise, such as commercial fishing, can be quantified in terms of the economic loss, the essentially intangible values of recreation and estuarine habitat are difficult to measure.

Recreational loss would have to be measured in terms of how many people don't swim or go boating in the Potomac River because it is polluted. It is far easier to find out how many people do go there even if it is polluted; even these values are hard to find.

The value of estuarine habitat is just as difficult to establish. There are now about 5.5 million acres of important estuarine marsh and wetland habitat remaining in the estuarine zone of the United States. Perhaps each acre is not valuable by itself, but the total habitat is irreplaceable. The problem of measuring the value can be illustrated by this example:

> A poor worker had been given a loaf of bread for his supper. On his way home he met along the road several friends who each asked for a slice of bread. Being generous, and since a single slice of bread is a small thing, he gave each of them a slice. When he arrived home he had only the wrapping left. Since his family couldn't eat that, they went supperless to bed.

How valuable is a slice of bread?

How valuable is an acre of estuary?

DAMAGE TO MARSH HABITAT

Delaware Bay

The following example shows how, in the Delaware Bay system, there

has been a steady attrition of estuarine marsh area for industrial development in recent years. The example is taken from testimony presented by Mr. Allston Jenkins, representing Philadelphia Conservationists, Inc., before a Congressional Subcommittee in March, 1967.

(1) "In 1955 The Tidewater Oil Company started acquiring some of the finest estuarine marshes in the State of Delaware for the purpose of constructing a large refinery in the vicinity of Delaware City about 30 miles north of the Bombay Hook National Wildlife Refuge. State conversation officials and citizen groups endeavored to persuade the company to locate its refinery on land other than the estuarine marshland. It was of no avail. Some 1,000 acres of productive estuarine marshes were purchased, filled-in, and lost as a natural resource.

(2) In 1961 the Shell Oil Company started a similar acquisition of estuarine marshes in Delaware upon which to construct a large refinery in the vicinty of Smyrna about 5 miles north of the Bombay Hook National Wildlife Refuge. Efforts of State conservation officials and citizen groups to persuade the company to locate on the upland instead of on the marshes have proved futile. The company has acquired some 1,000 acres of natural estuarine marsh

and is continuing a program of further acquisition. I am told that the vote of one member of a small township zoning board was the decisive factor in determining whether there should be 1,000 acres of prime estuarine resources or 1,000 acres of bottom silt landfill.

(3) Recently the B. F. Goodrich Company applied to the Corps of Engineers, U. S. Army, for a permit to dredge in the Chesapeake-Delaware Canal (the connecting link between the Delaware River Estuary and the Chesapeake Bay Estuary) for the purpose of constructing a dock and berthing facilities for a plant to be constructed on the edge of the canal. Over 1,000 persons attended a public hearing on the application on February 9. Over 90% of those attending were opposed to the granting of a permit. Yet this may not be decisive with the Corps of Engineers. The Corps is concerned primarily, almost soley, with the effect on navigation of the proposed dock and berthing facilities. If the company can show that the proposed facilities would not seriously hamper navigation it is not at all unlikely that the Corps will grant a dredging and filling permit.

(4) Two or three years ago the Sinclair Oil Company acquired 300 acres of estuarine marsh near Milford Neck, Delaware, 18 miles south of the Bombay Hook National Wildlife Refuge, for use as a tank farm

and unloading port.

(5) A recent newspaper article, confirmed by the New Jersey Division of Fish and Game, states that the Atlantic City Electric Company has acquired 4,500 to 5,000 acres of marsh between Stowe Creek and the Cohansey River along the Delaware River near Bridgeton, N.J. The company intends to construct a nuclear energy plant and industrial complex. The New Jersey Green Acres Program and the Division of Fish and Game had both marked this area for preservation. These are some of the finest estuarine marshes of the estuary."

Connecticut Coast

Connecticut State Board of Fisheries and Game "Tidal Marsh Area--A Summary as of February 1965" says that the earliest record that seems to have been accurately obtained gives a figure of 36.5 square miles. This figure was published in 1914 in the First Annual Report of theNew Jersey Mosquito Extermination Association. In the 1954 Wetlands of Connecticut, published by the U. S. Fish and Wildlife Service, about 21.7 square miles of this area remained, a reduction of 9,500 acres in 40 years. This reduction averages slightly less than 240 acres per year, slightly less than 1 per

cent per year.

A resurvey in 1959 led to the publication of a second "Wetlands of Connecticut, Revised June 1959". At that time these areas had been further reduced to about 20.2 square miles - 12,937 acres. This reduction averaged about 190 acres per year, slightly less than 1.4 per cent a year, 6.8 per cent for the five year period. Hence, while the actual acreage lost during this period is less than in similar periods, earlier, the percentage lost each year is increasing. A second resurvey in 1964 shows a further reduction to about 18.6 square miles - 11,900 acres for the areas of the 1914 survey. This reduction averaged about 200 acres per year, 1.6 per cent per year of the 1959 acreage, 7.9 per cent reduction in acreage over the 5 year period. Both percentage-wise and in actual acreage lost the 1959-1964 period is higher than was 1954-1959.

The data in the Wetlands publications are not directly comparable to those given above, since some upriver tidal marshes are grouped with the saline marshes. These are, in some cases, somewhat less vulnerable to destruction.

About 20,500 acres of tidal marsh in the State were rated for their value to wildlife in 1954. The high and moderate value acreage totalled about 13,000 acres, about 63 per cent of the area. The resurvey in 1959 showed a reduction of more than 1,300 acres,

leaving a total of 19,200 acres. Of the high and moderate value areas 12,600 acres remained, which represents a 3 percent loss in the more valuable tidal marsh during the 5 year period, a reduction in total area of about 6 percent. However, this is not the complete picture.

While more than 3 percent of the tidal marshes were completely or partially destroyed during this 5 year period, their value for waterfowl was not reviewed in 1959 or 1964, and much of the area that was of high or moderate value in 1954 may have been reduced in quality making the loss more severe than that recorded.

The total loss of tidal marsh tabulated in the 1954 and 1959 surveys is about 6 percent for the five year period. The loss for the five years 1959 to 1964 is about 7 percent.

The data on causes of marsh destruction do not fall into well-defined categories. Dredging for a marina and placing the fill on adjoining marsh represent two classes of destruction, but the figures do not separate the. Similarly, there are little data on the use to which filled areas are put--in housing, factories, boat storage, dumps. Major causes of this loss involved miscellaneous fill (48%); waste disposal (14%); roads and parking (9%); industry (7%); marinas (6%); housing (5%); recreational developments (3%); and schools (1%).

The loss of these marshlands can only be partly justified as needed for our economic growth and the demand of a growing population. Much of it has been the permanent destruction of an irreplaceable natural resource for a very temporary economic advantage. The accumulative effect has been change in the ecology of the Connecticut shoreline with the decline of formerly abundant species of fish and shellfish as well as the total disappearance of certain species of shell and finfish in specific areas.

DAMAGE TO FISH AND WILDLIFE

Chesapeake Bay

At the request of the Federal Water Pollution Control Administration the Bureau of Sport Fisheries and Wildlife conducted a study of "Fish and Wildlife Resources as related to Water Pollution" in the Chesapeake Bay Area. The report was issued in 1968; its results are summarized here.

The study area covered by biological considerations in this report included Chesapeake Bay and its tributaries, except the Susquehanna River Basin. This area includes the major drainages of the James, Rappannock-York, and Potomac Rivers as well as Chesapeake Bay and its minor tributaries. These drainages encompass virtually all of Maryland, a sizable portion of Virginia, and small segments of Delaware, Pennsylvania, and West Virginia.

To evaluate the relative effect of pollution on fish and wildlife

resources, the total resource potential under polluted conditions was compared with what would be available if pollution were eliminated. These resources potentials, both with and without pollution, were then compared to the expected user demand to determine their relative availability under both conditons. Specific data on present, future, or projected conditions are often minimal or lacking. Therefore, data analysis must be made on a general basis. This dictates that study results should be recognized as being relative in nature and utilized to gain an insight into problem areas. Figures quoted in the remaining portions of this narrative represent rounded data.

The 1960-1964 average annual commercial fishery harvest from the study area included 288,740,000 pounds of finfish and 107,584,000 pounds of shellfish for a total of 396,324,000 pounds.

Wetlands wildlife habitat occupied approximately 614,000 acres of the study area in the mid-1950's. Since that time, losses resulting from drainage, land fill, highway construction, and similar developments have reduced wetland habitat to a current area of about 558,000 acres or less. Wetland loss is thus 56,000 acres.

Pollution affects approximately 432,000 acres of finfish habitat and 42,000 acres of shellfish grounds for a total of 463,000 surfaces acres (adjusted for overlap), or about 14 percent of the study area's

fish habitat.

Average annual losses from significant pollution effects on 101,000 acres of finfish habitat and 42,000 acres of shellfish habitat amount to $1,861,000 and $1,090,000, respectively, or a total fishery loss of $2,951,000. No losses were assigned to 331,000 acres of neglibly polluted finfish habitat. Projected demand for both sport and commercial fishery harvest presently, or in the near future, will exceed the average annual sustained harvest capability from most individual habitat classes under existing pollution levels.

Table 23 of the report (Table IV 6.1) shown on the next page, gives the loss broken down by drainage basins. Finfish resource plus shellfish resources equals fishery resource.

Hudson River (Wappinger Creek)

The materials for this case study was obtained from the New York State Conservation Department, Fish and Game Division, Albany, New York. They graciously provided a legal case from their records. The case study quoted here is one of less than a half dozen situations during the past 40 years in which legal evidence, sufficient to be assured of a successful court case, could be obtained. Faced with the evidence an out-of-court settlement was reached.

The fact that in forty years less than six legal cases could be obtained along a river-estuary system as well developed as the Hudson

River points out the extreme difficulty in obtaining positive confirmation of a use damage.

On June 27, 1962 a delivery of No. 6 fuel oil was made to a storage tank which was not emptied sufficiently to accommodate all the oil delivered. An unknown quantity was spilled in Wappingers Creek, a direct tributary of the lower Hudson River. The Oil Company received complaints from property owners along the stream and decided, after skimming and pumping failed, to use a chemical, Ozene, which would be sprayed on the oil. It is estimated that about 30 gallons of Ozene was actually used in the stream spraying operation. It can safely be assumed that at least 20 gallons went directly into the waters of Wappingers Creek.

An abundance of dead fish was observed from the site of the spraying operation to about one mile downstream. Occasional dead fish were observed as far as four miles downstream. The fishkill was estimated at 10,000 fish, with about 75 percent being rough fish and minnow, 15 percent pan fish, and 10 percent trout.

A bio-assy was conducted using a solution of Ozene at the Rome Hatchery using spring water, and a solution concentration of 4.5 ppm ortho-dichlorobenzene. One hundred percent of test fish were killed in eight hours. On this basis, 20 gallons of Ozene would be capable of making toxic approximately 5,125,000 gallons of water. Since spraying would result in even higher local concentrations before complete

TABLE IV.6.1
Summary of Polluted Fish Habitat
Chesapeake Bay Area and Tributaries (Except Susquehanna River Basins)

Finfish Resources*

	Pollution Effects (Acres)					Total		Average Annual Loss	
	Negligible	Light	Moderate	Intense	Severe	Acres	Percent	Dollars	Percent
Chesapeake Bay Area	51	4,578	427	17,905	4	22,965	5.3	687,971	37.0
James River Basin	87,047	24,976	19,385	1,541	73	133,022	30.8	768,927	41.3
Rappahannock-York River Basins		593		199		792	0.2	13,549	0.7
Potomac River Basin	243,543	28,796	1,902	174	390	274,305	63.7	390,290	21.0
TOTAL STUDY AREA	330,641	58,943	21,714	19,819	467	431,584	100.0	1,860,737	100.0
Percent	76.6	13.7	5.0	4.6	0.1	100			

*Area not cumulative owing to overlap.

TABLE IV..61--(Cont'd.)
Summary of Polluted Fish Habitat
Chesapeake Bay Area and Tributaries (Except Susquehanna River Basin)

	SHELLFISH RESOURCES				FISHERY RESOURCES			
	Closed Areas		Average Annual Loss		Polluted Habitat		Average Annual Loss	
	Acres	Percent	Dollars	Percent	Acres*	Percent	Dollars	Percent
Chesapeake Bay Area	26,429	62.5	549,580	50.5	38,254	8.3	1,237,551	42.0
James River Basin	12,571	29.8	361,151	33.1	145,593	31.5	1,130,078	38.3
Rappahannock-York River Basins	3,077	7.3	173,433	15.9	3,869	0.8	187,032	6.3
Potomac River Basin	178	0.4	5,767	0.5	274,805	59.4	396,057	13.4
TOTAL STUDY AREA	42,255	100.0	1,089,981	100.0	462,521	100.0	2,950,718	100.0

*Area not cumulative owing to overlap.

mixing, the high concentration would kill in a time period of ten minutes or less.

The fishkill was the direct result of the application of a material called OZENE to the surface of Wappinger Creek. A $500 settlement for violation of Section 180 "Pollution of Streams Prohibited" of the New York State Conservation laws effected by out-of-court settlement. The oil spill itself was a violation of the classification standard established by the Water Pollution Control Board for Wappingers Creek.

DAMAGE TO WILDLIFE FROM OIL SPILLS

New Haven Harbor, Connecticut

The following quotation is from a release by Mr. O. E. Beckley, Supervisor, Game Management, Board of Fisheries and Game, State of Connecticut, dated March 28, 1961, and describes the death and value of duck life destroyed by oil resulting from a tanker with a rupture in her hull:

"On December 17, 1960, the S. S. Sister Katingo, a supertanker owned by the Nautilus Petroleum Corporation of New York, carrying a cargo of Bunker "C" oil, reportedly struck a submerged object somewhere off Brenton Reef, Rhode Island, causing a rupture in her port side.

> "According to the U. S. Army Corps of Engineers, a large quantity of oil was lost at the time of the impact, which

resulted in the blackening of Nantucket Island. The ship proceeded to her destination, New Haven Harbor, and arrived during the evening of December 17. Pumping activities were started early the next morning and were completed by noon the following day.

"It has been estimated that upwards of 240,000 gallons of Bunker "C" oil was lost, with a conservative estimate of over 42,000 gallons spilling into the confines of the New Haven Harbor. The oil quickly spread itself out upon the waters of the Harbor, breaking up into pools and slicks, coating bulkheads, seawalls, and beaches with black. Incoming tides carried it to upper shore reaches and then receded, leaving pools which in some areas were 4-5 inches deep. Approximately 10 miles of shoreline were blackened in the Great New Haven Harbor area. Within a week, marks of the spillage could be observed extending along approximately 20 miles of shoreline from Guilford to Milford. Evidence of the spillage was present on many of the off shore islands in the entire area.

"The Connecticut State Board of Fisheries and Game became aware of the problem on Tuesday evening, December 20. Investigations were initiated the following morning to determine the extent of the damage to wildlife.

"The first affected birds observed, while few in number,

served for Department game biologists as a grim warning of what might be expected in the days to come. Immediate efforts were made to initiate a clean-up operation and a series of contracts with the oil company and municipal officials and landowners was made in an attempt to expedite clean-up. But as negotiations proceeded the death toll grew. Dead, oil-encased birds appeared with greater frequency along the shore. Except for body form, these black, shrouded shapes with not a feather visible could hardly be recognized as ducks.

" A census of dead ducks was started on December 21. At the end of the first week of the investigation, 995 dead ducks had been counted in the Greater New Haven Harbor area. Of the dead ducks counted, approximately 400, or 40 percent were dabbling ducks, and 595, or 60 percent were diving species. Virtually all of the dabblers seen were black ducks with only a few (one) mallard and (two) baldpate observed. The dead diving ducks counted included approximately 300, or 30 percent scaup, 140 or 14 percent goldeneyes, 60, or 6 percent canvasbacks, and the remaining 10 percent included 35 scoters, 30 old squaw, 20 bufflehead, and 10 mergansers.

"In additon to ducks, other species affected included

herring gulls, horned grebe, loon, purple sandpiper, cormorant, clapper rail, and kildeer.

" Biologists estimated through reports and observations that at the time when the count of dead birds in the Harbor area was completed, an additonal 3,000 ducks had been affected. Of the total 4,000 birds affected, including 995 known dead at the end of the first week after censusing was started, it was estimated that 2,860, or 72 percent consisted of scaup, 500, or 12 percent of black ducks, including only a few mallard and baldpate; 340, or 9 percent goldeneyes, and the remaining 7 percent were made up of 85 canvasbacks, 80 scoters, 90 old squaw, 30 bufflehead, and 15 mergansers.

"Spot checks of hnuter bags were made from December 22, 1960, through the end of the gunning season on January 7, 1961. These bag checks, which were taken in an area extending approximately 20 miles both east and west from the New Haven Harbor, disclosed 185 oiled ducks of the 358 ducks killed, or approximately 52 percent oiled ucks for the entire area. During the period from December 22 to December 31, 1960, 55 percent of 293 ducks killed were oiled. During the period from January 2, through January 7, 1961, 35 percent of 65 birds killed were oiled.

" During the aerial inventory of waterfowl by Department

personnel on January 9, 1961, 33,187 ducks were observed in the 20 mile oil-contaminated area from Guilford to Milford. Species represented in this count consisted of: 1,462 blacks, 200 mallards, 20,130 scaup, 220 canvasbacks, 112 scoters, 28 goldeneyes, 8 old squaw, 5 mergansers, 2 bufflehead.

" It is a reasonable assumption that many of these ducks seen in the oil-contaminated area were affected by oil to varying degrees and could raise the total affected by many thousand.

"From observations conducted when the oil spillage first occured, through the end of the hunting season and during the abnormally cold period in January and February, it is conservatively estimated that at least 3,000 ducks perished as a result of being oiled.

"Commercial game breeder's quotations on the following species how that blacks sell for $3 each, scaup $30 each, goldeneyes $100 each, and canvasbacks $50 each. No prices were available for scoters, old squaw, bufflehead, and mergansers since they are ver difficult, if not impossible, to raise. It is estimated that replacement costs, if replacement were possible, would run well in excess of $100.000, based on current game breeder's prices.

"During the early stages of the investigation, approximately 400 live ducks, oiled to varying degrees, were collected by Department personnel and shore residents. Various types of cleaning agents were experimented with; many of these cleansed birds were returned to the water. Some were kept penned at a game breeder's farm to observe survival rates. Of 22 penned that were cleansed, only six were surviving at the end of a three-week period. Despite the efforts made to rehabilitate ducks, it is felt that their chance for survival is very poor."

Thames River, Connecticut

The information for this case study is quoted directly from the "Connecticut Newsletter: of the Connecticut Audubon Council dated February 15, 1969, Vol. 2, No. 8.

"An industrial oil barge ran aground, Thursday, January 16, 1969, on Bartlett's Reef near Waterford, Connecticut, causing an undetermined amount of heavy bunker "C" oil to be spilled in Long Island Sound. The Coast Guard apparently did not hear about this spillage until Saturday despite the fact that all oil ruptures are to be reported at once.

The beaches and rocky shore areas from Niantic to coastal Rhode Island were blackened with large globs of gooey tar-like oil.

"The Thames Science Center, 622 William Street, New London, was notified and were first on the scene with their three-man professional staff to appraise the situation. Several oiled-horned grebes were picked up completely covered and unable to fly. Red-breasted merganser, black duck, greater scaup, common goldeneye, bufflehead, surf scoter, Canada Geese, mallard, mute swan, common loon, herring gull, and greater black-backed gulls were all found oiled in various stages in their struggle for survival. As of January 30 the following is a summary of accurate figures of birds observed by the Thames Science Center Staff.

Species	Captivity	Known Dead	Oil Covered, In Natural Habitat Recovery Questioned	Totals
Common Loon	0	19	8	27
Horned Grebe	4	140	2	146
Mute Swan	2	3	18	23
Mallard	1	1	30	32
Black Duck	0	3	6	9
Greater Scaup	0	0	1	1
Common Goldeneye	0	1	18	19
Bufflehead	1	8	19	28
Red-breasted Merganser	13	13	36	62
Herring Gulls	0	0	31	31
Surf Scoter	0	1	0	1
Black-Back Gull	0	0	3	3
Canada Geese	0	0	85	85
White Winged Scoter	1	0	0	1
TOTAL	22	189	257	486

"On January 22, all beaches from the Connecticut River at Griswold Point, Oil Lyme to the Harkness Memorial State Park south of New London at the mouth of the Thames River were visually checked. The only beaches still with noticeable oil was Harkness Memorial State which was fairly cleared of the heavy oil. A policeman in Niantic said the tides cleared most oil from their beach.

"As of Friday, January 24, the Thames Science Center Executive Director, John Gardner, summarized the situation as follows:

"'The oil pollution was not severe because of the limited volume of pollutant in the water, the tendency of the oil to remain in globular form, its rapid mixing with sand, and dissipation by waves action. Beaches appear in good condition on the surface. Marine life seems to have minimal problems. Because of wintering populations most waterfowl suffered moderate losses. However, we know that 80 percent of the loons, 90 percent of the horned grebes and 23 percent of the red-breasted mergansers wintering in the survey area have been affected.'"

"A revised appraisal on January 30 concludes that:

"'At this time beaches are relatively clean, although

rocky beaches still contain varying amounts of oil. Marine life seems to have minimal problems. Algae on rocky shores is expected to die, but regrow by spring. Waterfowl deaths now stand at 189 (known and verified). Two-hundred and fifty-seven birds have been sighted with some oil fouling, and we expect that the majority of these will not survive. Seventy-four birds reported last time are unaccounted for at this time. It is normal for injured or sick birds to move into grassy areas or dense marsh areas where they die or are preyed upon by predators. Consequently, we assume the 74 birds not accounted for are dead. (If these are added to confirmed deaths it brings the death toll to 263). The 257 birds sighted with oil covering parts of their body are not expected to survive. Deaths are attributed to oil ingestion. All data based on actual field studies and confirmed reports. No estimates or projections included."

DAMAGE TO COMMERCIAL SHELLFISHERIES

Raritan Bay, New York and New Jersey

Exhaustive studies in Raritan Bay were carried out by the Public Health Service as part of the investigations resulting from shellfish bed closures and public health hazards resulting from pollution of Narragansett Bay. Most of the information presented in this case study was taken from the enforcement conferences which resulted from these investigations.

An outbreak of hepatitis in 1961 was traced to consumption of raw shellfish from the Raritan Bay. In 1963 the Public Health Service found the same level of pollution as in 1961 and the project scientist concluded that in that year this health hazard "precluded a safe shellfish industry and interfered with legitimate use of the waters of Raritan Bay."

The Bay was closed in 1961 to all shellfishing by order of the New Jersey State Commissioner of Health, Dr. Kandle.

Bathing has been restricted on most of the beaches on Staten Island along this bay (see case study on Staten Island beaches).

A total of 3,789 fishermen lost their livelihood in all of New Jersey due to closings, as of 1965. The Raritan Bay closing, therefore, would represent a maximum of 3,000 men out of work.

All 1961 and 1962 water samplings by the Public Health Service show a heavy FECAL bacteria count, both on mean average as well as for spot samples. (Lowest mean 50/100ml, highest 9,700/100ml.) The origin was traced to many insufficiently treated sewerage plants particularly at Atlantic Highlands, and Keansburg and raw sewerage from the Earle Ammunition Depot (N.J.) and seven sewerages serving a total of 3,000 inhabitants in Tottenville, Staten Island. Besides these, three additional sources of pollution are (1) the Narrows where sewerage from New York City passes through a "funnel," (2) the Raritan River, and (3) Arthur Kill.

Great Kills Park was a man-made landfill, where garbage was dumped as a fill. It was impossible to ascertain how much pollution could be attributed to this fill operation. Only the statement by witnesses that the landfill operation caused pollution of the adjacent water is available.

Raritan Bay covers roughly 90 square miles of which an estimated 5 percent was once harvested for shellfish. Thus, about 2,850 acres (A.S. Merrill) are suitable for shellfish. At the rate of 2,000 bushels of oysters on one acre (A.S. Merrill p.334, 1967 Conference--Pollution of the Navigable waters of Eastern New Jersey--, November 1967 FWPCA) or 2,000 bushels of clams per acre (Jerome, Chesmore and Anderson, 1967, "Study of Marine Resources of Beverly-Salem Harbor, Page 49) combined with a dockside price per bushel of $1.50, the loss per acre per year is $3,000. If 2,850 acres of the Bay were so utilized that total loss would amount to $8.5 million annually. These figures will vary as follows:

(1) 2,000 bushels per acre represents the upper limit of current bottom harvest yields. Three dimensional farming is already yielding over twice this amount per acre. On the other hand, a more average bottom yield would be on the order of a few hundred to 1,000 bushels per acre.

(2) The $1.50 figure is very low since a bushel of oysters currently (1968) brings about $10.00 in the New England

area. This would be the dockside landing value of the bushel. Then there is the expanded value of bushel or that represented by the flow of money and jobs generated by people employed in processing and marketing the product. The expanded value runs from five to ten times the dockside value.

The pollution of shellfish beds in Raritan Bay has resulted, therefore, in the following:

(1) loss of employment and loss of an industry

(2) an epidemic of hepatitis

(3) loss of recreational shellfish harvest

(4) loss of $8.5 million annually and five to ten times this amount if the expanded value is used.

From 1948 to 1960 Raritan Bay shellfish reaching the New York City market of 20,000 to 30,000 bushels a year brought $6.00 per bushel or $120,000 to $180,000 annual dockside value. A survey by the Northeast Shellfish Sanitation Research Center (circa 1965) indicated a standing crop of some 5,000,000 bushels of clams which agrees with the estimate made above.

Penobscot Bay, Maine

The "Report on Pollution--Navigable Waters of the Penobscot River and Upper Penobscot Bay in Maine", Merrimack River Project-Northeast Region, Boston, Masschusetts, February 1967, Federal

Water Pollution Control Administration, provided the information for this case study.

Penobscot Bay and River are troubled with at least four major types of pollution which affect the shellfish beds. Untreated or insufficiently treated sewage, poulty processing wastes, sulfite waste liqour, and heavy metal contamination from mining operations have compounded the problem of trying to reopen the closed shellfish beds.

The long axis of the Penobscot River-Bay-Estuary system is approximately 35 miles in length. Shellfish growing areas of the upper bay were first closed in 1946. Since that time, more and more closures have been required along the entire upper perimeter of the bay and the lower estuary. Increases in poultry processing and other industrial and commercial expansion have required a drastic increase in the acreage of flats and waters closed because of pollution. Some of the problem is due to heavy metals mining.

Levels of toxic metals are at or above the maximum of the normal range for shellfish. In the case of lead, the concentration is double or triple the maximum guideline recommended by the U. S. Public Health Service.

In addition to the high coliform counts, there is a problem in the Penobscot Bay area due to poultry processing. The following information gives a picture of the problems caused by the poultry

industry (Report on Pollution-Navigable Waters of the Penobscot River and Upper Penobscot Bay in Maine).

> "On June 28, 1966, the Maine Sea and Shore Fisheries reported finding floating chicken entrails in Stockton Harbor at the northeast side of Sears Island. They reported that these entrails had a total coliform value greater than 170,000 MPN/100ml. Again on July 8, 1966, floating chicken entrails were found by Fisheries personnel in Stockton Harbor at the same location. They also reported that on June 28, 1966, an animal fat film was found on the waters from the south tip of Sears Island to the north tip of Sears Island in Stockton Harbor. Large amounts of feathers have been reported found on Sears Island and Islesboro Island. A ferry running from Isleboro Island to Lincolnville, which is south of Northport, reported that their water intake screen had to be cleaned at least once a week in the past, due to chicken feathers clogging the screen. In the past, chicken entrails have been found all along the banks of Belfast Bay. During the period samples were being collected by the Merrimack River Project, there is no significant discharges of either feathers or entrails, indicating that either the new screening devices were working properly or that closer attention was given to maintenance of these screens.

"Sterile gauze swabs were placed at 21 stations for about five days. Salmonellae were found at five of the stations (poulty plant effluent). The United States Public Health Services Communicable Disease Center determined the serotype. The results clearly pointed out that poulty plant wastes are pathogenic to man since all Salmonella bacteria are pathogenic. Salmonellae were isolated from both swabs placed in the Penobscot River.

"The Maine Water Improvement Commission found that the dissolved oxygen placed the Penobscot River either in the nuisance condition or in Class D (Suitable for transportation of sewage and industrial waste without causing a public nuisance.) from Bangor to Bucksport. Zero D.O was found from Bangor to Winterport during the summer of 1963, with the oxygen sag curve moving downstream at low tide and upstream at high tide. This dissolved oxygen condition limits usage of the entire river below Bangor and prevents fish, including anadromous fish such as salmon, from passing through these waters."

Another problem is Sulfite Waste Liquor resulting from the processing of pulp using the sulfite process. Bioassays of Pulp Mill Wastes with Oysters, Biological Problems in Water Pollution, U.S. Department of Health, Education, and Welfare, Cincinnati, Ohio, 1965 showed that concentration of SWL above 10 ppm prevented the embryonic

development of the Olympic oyster from eggs to shelled larvae. Upper Penobscot Bay area had SWL concentration near 60 ppm and at low tide near Fort Point the value was about 100 ppm.

In November 1954, about five miles of shoreline and a fivefold increase in the total area of flats and overlying waters were added to the original Belfast Bay closure. Prior to this time, 50 commercial diggers had been licenced in the Belfast area alone.

Additional closures have been made periodically since 1954. Finally, by July 1, 1966, the last remaining open areas were closed, making the closure complete from Great Spruce Head in Northport up the Penobscot River and down the east shore to Castine.

For the total area of Penobscot Bay affected by the recent shellfish area closures, the estimated population was placed at 96,000 bushels of marketable soft clams, valued from a community standpoint (note: this is the concept used in other case studies as the expanded value...it is generally 2.5 to 7 times the dockside or landing value) at $1,876,000 to $5,216,400. Potential harvest during a second season was estimated to be 46,200 bushels. These would have a value to the community of from $896,800 to $2,494,800.

DAMAGE TO SHELLFISH HABITAT

Great Bay, New Hampshire

Two documents provided the information for this case study:

"Coastal Watershed" by the New Hampshire Water Pollution Commission, July 1965, Staff Report No. 51, and "A Biological Survey of Great Bay, New Hampshire by the Marine Fisheries Commission, No. 1, Physical and Biological Features of Great Bay and the Present Status of its Marine Resources," C.F. Jackson, Director, Biological Institute, University of New Hampshire, Durham, New Hampshire, March 1944.

Historical data indicate that the Great Bay area was at one time especially rich in natural resources, such as salmon, shad, cod, and various shellfish. Rapid decline or ultimate disappearance of many of these food fishes dates from the beginning of the industrial development of this region about 1800.

Great Bay and the tidal rivers afford some 2,815 acres of potential clam flats. Most of these are non-productive due to pollution, silt or the growth of Spartina. The situation in reference to oysters parallels closely that of clams. In early days the oyster fisheries probably exceeded in commercial importance those of the clam. In later years, however, this situation has been reversed, due first, to the growing scarcity of the oyster, and secondly, to restrictive legislation.

Clams and oysters were once harvested in Great Bay Estuary. In 1938 the estuary was closed to the commercial production of clams due to bacterial pollution. In his biological survey of Great Bay

in 1944, C. F. Jackson estimated a loss of $2 million annually on clams in Great Bay. Thus with no commercial utilization of clams in Great Bay over the last thirty years, a loss can be calculated at $60 million since it is based on a per bushel value of $1.50 and the 1944 price of clams. The current per bushel price of clams in the New England area is nearly $10.00. Thus the loss, dockside, may be nearly seven times greater or nearly $420 million since 1938.

Oyster production in Great Bay Estuary has also been closed commercially since 1938. A recent survey estimated the total acreage of oyster beds at roughly 25 acres in Great Bay. At a production of 500 bushels per acre, this would result in a loss of 12,500 bushels annually. Oysters at $10 per bushel would then bring in $125,000 annually. Over the thirty-year period since harvesting has been closed this loss due to pollution amounts to nearly $4 million.

All tributaries of Great Bay are dammed. Many of these dams have existed since 1800 and provide a block for fish such as salmon, alewives, and American shad, which need freshwater areas to complete their life cycles. The lost value of such fisheries over the years would run into many millions of dollars to both commercial and, more recently, sport fishermen. It should be pointed out that no definite estimate of this loss has been made but it is definitely measurable.

Moriches Bay and Great South Bay, Long Island

Information for this case study was supplied by contract investigations conducted as part of the National Estuarine Pollution Study, two federal enforcement conference proceedings and a report of the Nassau-Suffolk Regional Planning Board (IV-6-5).

Up to 7 million ducks annually live in farms located on Moriches Bay and parts of Great South Bay. These ducks are a source of pollution to the Bays. In one form, they cause the closing of valuable shellfish beds due to high coliform counts. Another form of pollution they create is BOD and eutrophication due to the ducks sludge which covers the bottom of the bay in some sections.

Studies conducted by the Division of Laborators and Research of the New York State Department of Health on duck wastes have shown them to be high in solids, BOD, nutrients, bacterial content, and constitute a public health hazard. It was found that the strength and volume of the wastes reaching the waste stream depended on the number, age, activity, position of ducks in the pens, amount of rainfall, runoff area, normal water use at the farms, and availability of water to the ducks.

Coliform densities were found to vary from a median MPN of 5.8×10^6 per 100 ml to 60×10^6 per 100 ml. Typical water usages ranged from 0.290 mgd to 3.0 mgd per farm and from 14 gal. to 120 gals. per day per duck.

Since 1940, there has been a decline in the oyster and fish production of Great South Bay. These conditions have coincided with the buildup of the duck industry in the areas surrounding Moriches Bay...The wastes from the duck farms effectively fertilized these waters but with a low ratio of nitrogen to phosphorus.

As a result of the increased nutrients, especially phosphrus, the waters of Great South Bay have exhibited increased algal populations. Heavy growths of algae developed in the early spring and persisted through summer and fall. At its peak, the concentration of algal cells exceeded 10 million/ml. The dominant bloom algae was a small, unicellular species often termed "small form." This algae differed greatly from the flora typical of bays and estuaries in the same region and its persistance over long periods of time eliminated the typical seasonal succession of forms in the bay.

The decline of the oyster industry was directly correlated with the increase in the "small form." This was due to the fact that the optimum conditions for oyster growth included a mixed algal population. Although oysters do feed on the "small forms," these algae are an inadequate nutrient source. Serpulid worms which are capable of effectively utilizing the "small forms" for food have overrun the oyster beds periodically and thereby adversely affected oyster production by competitive exclusion.

The report of the Nassau-Suffolk Regional Planning Board, "The Status and Potential of the Marine Environment," states that "the

oyster industry has declined 99 percent in the past 50 years from 50 million dollars to 1/2 million dollars." (p. 2-7)

In addition to the habitat damage caused by the duck farm wastes, there are productive areas of shellfish beds closed because of bacterial contamination.

The closed acreage, about 6,000 acres with 4,500 usable acres at 5 bushels per acre at $10 per bushel, is estimated to be capable of producing clams with a dockside value of $225,000 and an expanded value in excess of $2,250,000 annually. This loss has been in effect for 25 years. Adjacent open waters provide the proof of use and the dollar values used to estimate the loss.

DAMAGE TO RECREATION

Staten Island Beaches

The information presented in this case study were obtained through interview of the Manager of the Parks Department, Staten Island, F. D. R. Boardwalk, the Manager of Wolfe Pond Park, Staten Island, in April 1969. Additional information pertaining to average coliform density on the Staten Island Beaches was obtained from the New York City Department of Health. Former uses of the beaches are a matter of record and can be verified through old newspaper clippings of the Staten Island Advance as well as discussion with older residents of New Jersey and Staten Island. These statistics are not available in published form and have been verified and rechecked by interview and

investigation as part of the contract studies of the National Estuarine Pollution Study.

The F. D. R. Boardwalk Midland Beach, Great Kills Park, and South Beach are regularly posted in the summer season. The signs read "Not Recommended for Bathing," and are posted by the Board of Health of the City of New York. When this happened in 1968, it resulted in a drop of 50 percent in the use of these facilities.

Bathhouses and parking facilities were originated in the 1930's. The construction which is now evident dates from a reconstruction in 1950.

South Beach has two parking facilities for 800 cars each, Midland Beach for another 800 cars, amounting to a total of 2,400 cars parking facilities.

On a non-posted average day, 1,300 cars will use these lots. On a holiday, 2,000 cars will be using them. The admittance per car is 50 cents, therefore, $650 and $1,000 are paid for parking respectively. When the beach is posted "Not Recommended for Bathing," an average day's parking fees amount to $325 and a peak day yields $500.

The beaches are open from May 24 to the weekend after Labor Day. With Memorial Day, July 4th, and Labor Day offering a total of 9 days peak activity at a loss of $500 per day in parking fees, a total loss of $4,500 per season for peak activity is attributed

to pollution. In June, July, and August, weather and conditions permitting 25 days average usage per month is available. If the loss of use due to pollution runs at $325 a day, the loss computes to $8,125 per month and for the total season to about $24,000 in round figures. Conservatively speaking, the total annual loss amounts to $30,000 in parking fees alone!

It is most important, however, that these figures in dollars by no means reflect the true loss in recreational facilities due to pollution. Fifty cents is charged whether one car with one passenger or a whole family parks in the parking lots. Most of the time whole families are affected in this figure of 50 cents per car, usually most families from modest if not low socio-economic background whose residences are within easy reach of these beaches, such as Newark, Elizabeth, Manhattan, and Staten Island.

The economic loss resulting from loss in corollary sales is not included: soft drinks, ice cream, and snack sales which constitute a business for many seasonally employed people are not included in this case study but have to be con idered.

The present condition of loss in recreational facilities was reported by officials of the Park Department and verified through a direct interview on April 1969, with the Manager of the Parks Department, F.D.R. Boardwalk. The pollution was verified by N.Y.C. Department of Health. Coliform count at Midland and South Beach

is in the order of 7,000 to 9,000 MPN/100 ml; the greatest pollution exists at the Narrows.

The sewage and human waste from New York City area decreases by dilution towards the middle of Staten Island shore and increases where contact with the Jersey shore is greater. The human waste materials emanating from these two points causes the lowest coliform density point at Wolfs Pond Park. The latter is never posted according to the guard interviewed on location. However, when the word spreads that the other beaches have been posted, the attendance at Wolfs Pond Park also drops up to 25 percent in spite of Wolfs Pond Park not being posted.

The fact that the parking lots, and hence the beaches themselves, are hardly ever used to full capacity indicated that even when the beaches are not posted, public opinion cannot react on a "day-to-day" posting basis and people consider the beaches as "polluted" at all times. The loss damage estimates could use the full parking lot capacity because the Staten Island area is in the midst of the largest metropolitan complex in the world with a corresponding need for any and all recreation facilities especially during the hot summer season when the requirement for providing activity for teenagers and unemployed is most critical.

Santa Barbara, California

An emission of oil originating in the vicinity of an offshore drilling platform operated by Union Oil Company began on January 28, 1969, and was not contained until 12 days later; subsequently, additional oil began leaking through the ocean floor.

The oil came ashore in the vicinity of Santa Barbara and covered beaches that are a major recreational resource of the area. The Union Oil Company accepted responsibility for cleaning the beaches and other property damaged by the oil, and by June 1, 1969, had spend $4,600,000 for this purpose. (IV-6-6, IV-6-7).

DAMAGE TO NAVIGATION

Charleston Harbor, South Carolina

The information for this case study was obtained from the U. S. Army Corps of Engineers Report "Survey Report on Cooper River, South Carolina (Shoaling in Charleston Harbor)," 1966, and from "A Retrospective Economic Analysis of the Santee-Cooper Project," December 1967, by William Augustus Ward.

As part of the national plan to minimize unemployment during the great depression of the 1930's the South Carolina Public Service Authority was formed for the purpose of building a large dam, water supply, flood control, navigation lock, recreation and employment opportunity complex. Cost-benefit analysis was needed to show that

the project merited the loan of federal funds. The construction complex is referred to as the Santee-Cooper Project.

In 1967 a study to check on the effectiveness of a cost-benefit analysis made twenty-five years previously was undertaken. Part of this analysis revealed that as a result of construction and hydraulic rerouting of rivers the silting in Charleston Harbor increased from what was estimated at $18,000 annually to an actual cost of over $2,029,756 annually. For every year in the future that the hydraulic regime of the Harbor is not restored to a more suitable mode of circulation there will be a dredging cost of roughly the same magnitude incurred.

The diversion of the Santee River into the Cooper River constituted a remarkable engineering experiment. The designers of the diversion apparently foresaw no adverse effects. To the contrary, they felt that the effects of the added flow would be to flush out the harbor and prevent any serious pollution from every occurring. As a result, the discovery that the shoaling rates were increasing in the harbor apparently came as a complete surprise to everyone. By 1947 the Corps of Engineers was undertaking model studies to try to determine a solution to the problem.

The finding of the Corps in their model studies at Vicksburg, Mississippi, indicated that the increased flow into the harbor area had created a partially-mixed estuary. That is, the ratio of

freshwater to salt water in the harbor area was such that a definite interface developed which moved longitudinally up and down with the tide. The dense saltwater was overlain by the freshwater inflow. As the freshwater flow increased to 15,000 c.f.s., the bottom flood currents became greater in duration over the bottom ebb currents. The effect was to create a net upstream movement of the bottom currents in the saline region of the harbor area, a condition which created a trap at the bottom of the estuary preventing the movement of settling materials out to sea.

At about the same time the Santee-Cooper Project began operations, the project depth of the Charleston Harbor was changed from 30 feet to 35 feet. This further complicated the dredging problem for two reasons: first, the Corps had 5 additional feet of depth to maintain and second, the dredging itself loosened the accumulated silt outside of the shipping channels and allowed it to slip into the channels. The Corps maintained, however, that the natural depth of the Charleston Harbor had exceeded 35 feet, and that the greater project depth in itself would not have constituted much of a problem.

From its study of the shoaling problem in the Charleston Harbor, the Corps estimated that the Santee-Cooper Project was responsible for approximately 85 percent of the shoaling in the harbor. The rest, they said, would have occurred without the project.

In 1965, dredging by the Corps was done at a cost of $2,237,949. It was estimated by the Corps that commercial shippers spend $100,000 on dredging operations while the Navy spent $50,000. Assigning 85 percent of this cost of the Santee-Cooper Project, a negative benefit of $2,029,756 was attributed to operation of the project is 1965.

The most competent engineering firms in the nation were employed in designing and constructioning the project, and the design was checked and approved by the United States Army Corps of Engineers. Still, the analysis by the planners and engineers of the project yielded estimates of benefits and costs which were substantially different from those which actually occurred. Part of the discrepancy was due to simple optimism and even some bias on the part of the analysts. An equally large part seemed to be due to the inability of man to see even 25 years into the future. In the case of silting, the state-of-the-art was such in 1930 that no adverse effects were envisioned. As a result the dredging bill jumped from $18,000 to $2,029,756 annually.

SECTION 3. TRENDS IN ESTUARINE ECOLOGY ASSOCIATED WITH MAN'S ACTIVITIES

The future character of estuarine ecological systems in the United States will be determined by present and future pressures affecting the estuarine zone, public decisions, and by the actions resulting from public policy. Thus, the future nature and operation of the total biophysical environment will be shaped primarily by the socioeconomic and institutional environments discussed in this report.

Existing estuarine ecological systems will continue to operate either in long-established dynamic patterns of chemical cycling, water circulation and species behavior, or these activities will be increasingly dominated by man's activities. Man's activities generally result in great stresses on established plant, animal and chemical processes, if not total system modification. These activities may be controlled by decisions made in the socioeconomic and institutional environments to minimize impacts on the existing estuarine systems, thus retaining their structure and operation; or, the energy sources and stresses associated with man's activities may be allowed to dominate estuarine processes and, in effect, create wholly or partially different systems.

From a strictly empirical or descriptive viewpoint, the emerging new systems associated with man's activities are neither good nor bad per se; the determination of values relating to these modified systems must be made within the existing or potential socioeconomic and institutional frameworks. Values will be set in the market place, which include all the mechanisms whereby society normally measures the worth of goods, services and wages, which in turn largely determine the pressures placed on estuarine systems. The non-market system also determines values through the expression of choices expressing social costs and benefits not measured in standard economic terms. These two major components of value-setting must be balanced if modification and ultimate destruction of existing estuarine ecosystems is to be avoided.

STRESS AND ESTUARINE ECOLOGY

Estuarine ecological systems consist of populations of organisms, flows of water, pathways of cycling chemical elements, and organizing mechanisms which are all tightly interrelated. These systems constantly adjust as the principal elements in their operation change in character, quantity and composition. Thus, estuarine ecological systems, as with all ecological communities, are subject to change, and either successfully adapt, or are replaced by other systems.

Maintenance of estuarine ecological systems is dependent on an effective flow of energy and mineral cycles; it is these factors that most fundamentally determine the important features of system yield, system stability and water quality, rather than the presence of large, visible forms of life. In estuaries, the sun operating plant production processes and the mineral and organic fuels entering from fresh water inflows are the most important energy bases. Both the ecosystem components and overall energy flows primarily originating from these sources must be maintained without acute shortages or excesses. If the balance of cycling fails, estuarine ecological systems become less effective in processing food energies and are subject to replacement, either as a whole, or by substitution of their parts.

A stress on an estuary is a process which drains available energy. Stress can be either direct as in the case of harvesting fin fish or shellfish from the system, or indirect as happens when increased turbidities shade out light or when some substance such as phenol is added to the aquatic system, either causing mortality or demanding special adaptive work on the part of surviving organisms to sustain life. Energy drains on existing organisms may also occur when excesses of nutrients added to the system deplete the available oxygen necessary for respiration.

In general, estuarine system diversity and organization is highest where energy inputs are high and stresses are low as in many relatively unmodified temperate and tropical estuarine areas. Conversely, those systems where stresses are high and sources of energy low are characterized by low species diversity and relatively simple organization as in the case of artic systems or those greatly modified by man. Thus, the relative diversity and organization of estuarine systems are due to both "natural" occurrences, such as sunlight, temperature fluxes and nutrient inflows, as well as those associated with man's activities such as modification of circulation regimes, addition of pollutants to the water, and thermal waste heating.

Estuarine systems in the United States are almost universally stressed by both natural and man-induced processes. The relative mixture of man-caused and naturally occurring stresses, and their respective roles in estuarine modification, are presently little known, and difficult to separate. It is certain, however, that the stresses resulting from man's present and potential activities in the estuarine zone play a decisive and increasing role in the foreseeable future operation of estuarine ecologies. Therefore, the following discussion focuses upon man's activities as they relate to modification of existing estuarine systems.

MAN'S ACTIVITIES AND ESTUARINE SYSTEM STRESS

Part IV, Chapter 4 showed the presently identifiable trends associated with population and economic development and with specific activities affecting the estuarine zone. At present, however, the rate of change effected by these trends on estuarine ecological systems is little known. The most recent work by ecologists is generally concerned with identification of system types, the development of general theory, and the measurement of system characteristics and operating phenomena. Much is known about certain elements of estuarine ecological systems, such as temperatures, salinities, abundance of certain biotic communities, but the specific processes and causal relationships of complex whole systems and interacting subsystems have only recently been partially understood.

Modification of estuarine ecological systems is nevertheless a trend which can be qualitatively, if not quantitatively, observed. Figure IV.6.1 indicates the general relationships between man's activities and estuarine ecological system modification.

The Nation's population and economy have expanded rapidly in the recent past and will continue to grow substantially in the foreseeable future. Moderate projections indicate a doubling of national population by the turn of the century. Much of this growth,

FIGURE IV.6.1
SELECTED ELEMENTS OF ESTUARINE ECOLOGICAL CHANGE DUE TO MAN'S INFLUENCE

Economic and Population Growth	Some Major Resulting Agents of Modification		Identified Stressed Systems Related to These Activities
1. Urban-Suburban Expansion in Response to Population Growth and Economic Opportunity 2. General Economic Growth Diversification, and Sophistication 3. Expansion of Specific Activities Related to the Estuarine Zone --Marine Fisheries --Civilian and National Defense Transporation --Marine Mining and Processing --Outdoor Recreation --Waste Discharge	1. Waste Discharge	Municipal Industrial Agricultural	Sewage Wastes Seafood Wastes Pesticides Thermal Wastes Radioactive Wastes Papermill Wastes
	2. Dredging	Navigation Mining and Processing Land Development	Dredging Spoil Phosphate Waste Destruction of Wetlands Altered Currents Salinities, etc.
	3. Physical Structures	Fresh Water Impoundment Diversion, etc. Piers, jetties, Hurricane Barriers, etc. Aids to Navigation	Impoundments Acid Waters Brine Pollution

The Multiple-Stressed System: Ecology of The Future?	Some Components in the Resulting Multiple-Stressed System
Example of One Major Economic Component →	Development of Petrochemical Complexes
Resulting Activities	
Waste Discharge --Municipal --Industrial --Ships	Sewage Waste Dredging Spoil Impoundments
Transportation	Petroleum Stores
Dredging and Filling	Pilings Brine Pollution
Population Growth and in-migration	Petrochemicals
Development of Secondary and Marginal Activities	Etc.
Shoreline Development, etc.	

probably more than one-third, will occur in the estuarine zone. Population growth will spur the expansion of urban and suburban developments. Major portions of urban development will develop along all major coastlines of the Untied States -- particularly the Atlantic Coastline north of North Carolina, Florida, the middle portions of the Gulf of Mexico and California. The economy will also expand both in scope and diversity to meet the demands of an increasing, wealthy population. Much of this economic activity will be centered on or closely adjacent to the Nation's estuaries and coastal shoreline. These economic activities will vary from place to place due to the location of natural resources and the demands for these resources, historic circumstance, availability of markets and changes in technology.

The general growth of both the population and economy is reflected in expanding trends noted for more specific activities related to the estuarine environment: marine fisheries, civilian and national defense transportation, marine mining and processing, outdoor recreation and waste discharge. All of these activities, as well as the associated secondary and marginal activities located in the estuarine zone, will intensify in future years. Marine fisheries and outdoor recreation are highly dependent upon naturally occurring properties of estuarine ecological systems. Transportation, mining and waste discharge are much less tied to these

systems, although at some point in the continuum of degradation these too would be adversely affected.

The case has been made that although all of these activities vary in their impact and dependence on estuarine systems, they all tend increasingly to modify those systems in a multitude of ways.

There appear to be at least three forms of estuarine system modification common to the specific activities described above: waste discharge, dredging, and construction of physical structures. In other words, these activities, and many others, contribute significantly to not only one identified form of estuarine system modification, but are usually responsible for a number of alterations of the biophysical environment.

Although generalizations about the effects of man's activities on estuarine ecology are hazardous at best, the following results generally characterize the modifications associated with significant waste discharges, dredging and filling, and construction of physical structures either on fresh water inflows or in the estuaries themselves:

(1) Productivity of biotic communities is generally reduced. This is due to many factors including reduction or over provision of nutrients, abrupt

changes in temperatures and salinities, changes in circulation patterns, and destruction of physical components of the system.

(2) Species diversity and organization is simplified.

(3) Trends toward severely modified ecosystems are established.

A review of recent literature indicates, however, that although these effects appear to be generalized, individual estuarine ecological systems must be studied in detail to establish precisely the parameters of change involved. Due to the complexity of the systems themselves, and of the causal interactions attributed to man's activities, no attempt can be made to establish national and regional trends in estuarine ecology. At this stage of knowledge such trending, based on scientifically tested information, is impossible. Yet one kind of estuarine ecological system does seem to be increasingly prevalent in the estuarine zone, and may become the predominant type if the impact of the socioeconomic environment on the biophysical environment continues unchecked.

THE MULTIPLE-STRESSED SYSTEM: ESTUARINE ECOLOGY OF THE FUTURE?

It seems clear that most, if not all major estuarine areas in the continental United States are now or soon will be affected by disturbances of more than one identifiable type. These systems are

characterized by heterogeneous patches of chemicals, fertilized waters, waters low in available oxygen, turbidities, acids and other conditions alien to normal life of estuarine ecosystems. The multiple stressed situation is possibly the Nation's most urgent estuarine problem because the condition is a mixture and the causes several. The stress of many different kinds of wastes may be more difficult for an ecosystem to adapt to than separate types of wastes acting alone. The continual fluctuations require more kinds of adaptation than there may be food energies to support. Some bays receiving mixed wastes which are primarily nutrient of non-toxic nature may develop extremely high metabolic rates and high rates of photosynthetic production. Such bays are almost micro-organism cultures, but have active larger animal populations too. Potentially such fertile waters are a food producing resource, although we know relatively little about the conditions for management of these mixtures which will channel energies into products of use to man, effectively mineralize the wastes, and stabilize the ecosystem.

Areas already noted as exhibiting these characteristics are, not surprisingly, those systems associated with concentrations of population and economic activity such as Boston Harbor, New York Harbor, Raritan Bay, portions of Chesapeake Bay, Tampa Bay, Galveston Bay and San Francisco Bay.

In a typical example, which is found in Galveston Bay, one major development alone, the petro-chemical complex, is identified as contributing twelve major sources of modification to this naturally rich estuarine complex. At least seven identifiable stressed systems result: sewage waste, dredging impoundments, petroleum shores, pilings, brine pollution and petrochemical wastes (IV-6-8).

Situated at the upper end of Galveston Bay, Texas, is the Houston Ship channel along which are located dozens of major industries that release wastes. Refineries, petrochemicals, sanitary wastes, and many others go into waters that pass out into Galveston Bay. The dredged channel is 40 feet deep, floored with waste sludge and generally black, and sometimes stratified with more saline waters on the bottom. Conditions are patchy, often low in oxygen, and often with high concentrations of oxidants and reducing compounds.

Similarly, one of the most fertile estuaries in America is Tampa Bay, that receives municipal wastes, food processing wastes, the outflows from phosphate district of Florida, and many other wastes. There are high concentrations of cells, nutrients, and other organisms. High fertility persists from low salinities in small headwaters to the full salinities at the mouth under the Skyway bridge. The Florida red tide is a recurring phytoplankton bloom of a dinoflagellate Gymnodinium breve that is poisonous to fish. This red water develops fish-killing blooms in high salinity waters off

the west coast of Florida and sometimes within the lower bay. The relationship of the fertile bay culture waters to the red tide outside is still uncertain and under study. However, the high fertility has not destroyed the general middle salinity characteristics of the ecosystem of the main bay where oysters, copepods, pinfish and young shrimp are abundant. Much of the area has been disturbed in dredging and filling although there are still large areas of shallow ecosystems that serve as fertile nurseries (IV-6-9).

Examples of severe modification and the resulting multiple stressed systems could be multiplied many times. The point is that nearly every trend noted in the socioeconomic environment in the recent past, and in the future, indicates that much of the estuarine zone is likely to receive these multiple man-caused stresses. Thus, the estuarine ecological system of the future appears likely, if past use trends continue, to be characterized by a new emerging "stinko" environment. Clearly, reliance upon existing use, management, planning, economic restraints, and technology to provide solutions to this trend are inadequate. It is essential that the socioeconomic and institutional environments be mobilized to reverse this seemingly inexorable destruction of the irreplaceable estuarine ecologies of the Nation.

SECTION 4. RESOLUTION OF USE CONFLICTS

Use damage and ecological disasters are not necessary features of civilization in the estuarine zone, but use conflicts will continue to exist as more and more demands are made on the natural environment. The ability of any management authority to prevent use damage and to resolve use conflicts depends not only upon its institutional composition and legal authority, but also upon the social, economic, and biophysical characteristics of the estuarine management unit within its authority is exercised.

The analyses of social and economic values of the estuarine zone examined concurrently with the similar analyses of use conflicts, pollutional effects, and use damages form the basis for this discussion of those means by which use conflicts can be resolved through the application of technical knowledge, i.e., technical management.

The primary objective of technical management is to accommodate the needed and desired uses of any estuarine management unit within that system without overall damage to the biophysical environment. The ability to achieve this objective depends on the boundaries of the management unit and upon the means available for resolving both prohibitive use conflicts and restrictive use conflicts.

MANAGEMENT UNIT BOUNDARIES

The impact of the social and economic requirements of civilization on the natural estuarine environment is the technical problem with which management must deal, and effective control of this impact can be maintained only if both the major sources of damage and the geographic range of their influence are subject to unified control.

Estuarine use conflicts and damages involve activities and effects concerning both land and water.

Many of the wastes which damage the estuarine environment originate from cities, industries, and other activities on the land, and control of the wastes from such sources is essential to effective management. Shoreline development limits access to estuarine areas as well as modifying some parts of the estuarine environment.

An estuarine management unit, therefore, should consist not only of the estuarine waters, bottoms, and associated marshlands; but it should also include all of the shoreline surrounding the estuarine waters themselves and as much of the adjoining land as is necessary to regulate the discharge of wastes into estuarine waters.

Effective control of water quality is one key to effective technical management, and one essential requirement in accomplishing this is the

ability to monitor water quality constantly and consistently. While the details of water quality monitoring are based on needs within individual estuarine systems, it is necessary that management unit boundaries be chosen so that the managing authority can measure both the quality and quantity of water entering and leaving the management unit. This is essential both to give warning of any incoming water quality degradation and to safeguard other estuarine environments by warning of any outgoing water quality degradation.

The size of the estuarine management unit is in itself a highly important factor in the technical management of estuarine systems. In a very small management unit it may be impossible to accommodate more than one use, thus making futile efforts to resolve use conflicts and achieve multiple use. For example, the maintenance of a commercial oyster fishery in the midst of a dredged navigation channel might offer the same problems in achieving multiple use as would the maintenance of a commercial chicken ranch in the middle of Kennedy International Airport. Conversely, in very large, highly developed, management units it becomes difficult to deal with individual problems in sufficient detail to control use conflicts effectively.

The boundaries of viable estuarine management units are generally governed by social, economic, and political factors rather than the sizes of the estuarine systems they include. Thus, the capability of technical management to resolve use conflicts in some management units

may be severely limited by external factors and it may therefore be necessary to forego some uses because of the small size of the estuarine resource available for use.

RESOLUTION OF PROHIBITIVE USE CONFLICTS

Those uses which exclude other uses generally involve modification of the shoreline, marshes, or bottoms by dredging, filling, or the building of a permanent structure. Such activities may not only immediately affect the estuarine morphology and habitat, but they may also cause widespread, long-range changes in the ecosystem.

The evaluation of the effects of prohibitive uses on the estuarine environment is probably the most difficult problem currently facing technical management. The immediate and obvious effects of the habitat loss associated with such uses can be measured and described fairly easily, but the ultimate results of the modification of water movement patterns and flushing characteristics can only be estimated in general terms. The need for research on such problems is discussed in Part VI, Chapter 3; until a sufficient amount of knowledge is accumulated, however, the only useful guide is comparison with occurrences in similar systems.

In nearly every problem associated with prohibitive use conflicts, however, the area of primary concern is the effect on the estuarine ecosystem

of any physical modifications proposed; the limitations of knowledge outlined above, therefore, present a critical problem in present efforts to resolve prohibitive use conflicts.

The great amount of modification that has already occurred in the estuarine zone has already resolved the problem of use conflicts in some estuarine systems by pre-empting or usurping a part of the estuarine resource for a single purpose, in many cases making modifications too expensive or otherwise too difficult to change in spite of their effects on the local environment.

There is little that can be done directly to correct environmental damage associated with past changes, but future demands for prohibitive use in a management unit can be resolved through application of past experience.

Allocation of part of the estuarine resource for an exclusive single-purpose use is a necessary fact of estuarine management. The shoreline is a necessary location for shipping docks and for swimming beaches, but they cannot both occupy the same place on the shoreline. Similarly, frequently dredged channels and oyster beds cannot occupy the same space at the same time. Resolution of such conflicts can be achieved by allocation of adequate space to each use through whatever institutional mechanism is established.

A more difficult problem arises where there is involved a massive dredge or fill operation with its concomitant immediate effect on the ecosystem. When such modifications are a necessary or desirable development of the environment it may be necessary to forego the habitat use; however, in many cases it may be possible to create new, equivalent habitat in a different part of the management unit, or it might be possible to restore part of the damaged environment.

For example, in recent negotiations concerning the dredging of phosphate rock along the Georgia coast, the company involved proposed to rebuild over 3,000 acres of the marsh that would be destroyed in the mining operation.

While the resolution of prohibitive use conflicts requires the abandoning of one use in favor of another, the potential for carrying out any modifications necessary so as to increase habitat value as well as economic value should be a key factor in the resolution of such problems.

RESOLUTION OF RESTRICTIVE USE CONFLICTS

Disposal of liquid wastes to the estuarine environment is the major restrictive use impact of the socio-economic environment. This use conflict can be resolved completely either by treating all wastes to such an extent that they do not interfere with any other uses or else removing them entirely from the environment.

Technology exists to provide thorough treatment for nearly every kind of municipal and industrial waste, and there is no reason not to provide treatment sufficient to protect the environment from damage and to permit other uses. Treatment requirements for different wastes may vary from place to place according to local conditions, but damage to the environment and restriction of other uses can be prevented.

Water quality standards have been set and are now being implemented in all the coastal states. These standards are the foundation upon which the effective control of estuarine pollution rests, and they provide the framework within which technical management can effectively operate.

As pointed out earlier in this chapter, however, estuarine waters even in busy harbors are used for recreational purposes by those who cannot afford to go elsewhere, regardless of whether the waters are safe for body contact or not. Also the role of the estuarine zone as a nursery for some fish, passage for others, and a residence for still more is readily apparent although its full implications in the energy conversion chain are not understood. For these reasons the water quality goal of estuarine management should be to keep all waters safe for direct contact by humans and also usable as a fish and wildlife habitat.

SECTION 5. SUMMARY

Loss of use and use damage in the estuarine environment are the direct results of unrestrained exploitation of estuarine resources. The examples presented, limited as they are by the difficulty of measuring use damages, show clearly the impact of one use on another and give a foretaste of the extensive damage that will occur if unrestrained exploitation continues.

Effective technical management of the estuarine zone requires the application of all pertinent existing knowledge to the resolution of use conflicts in estuarine management units.

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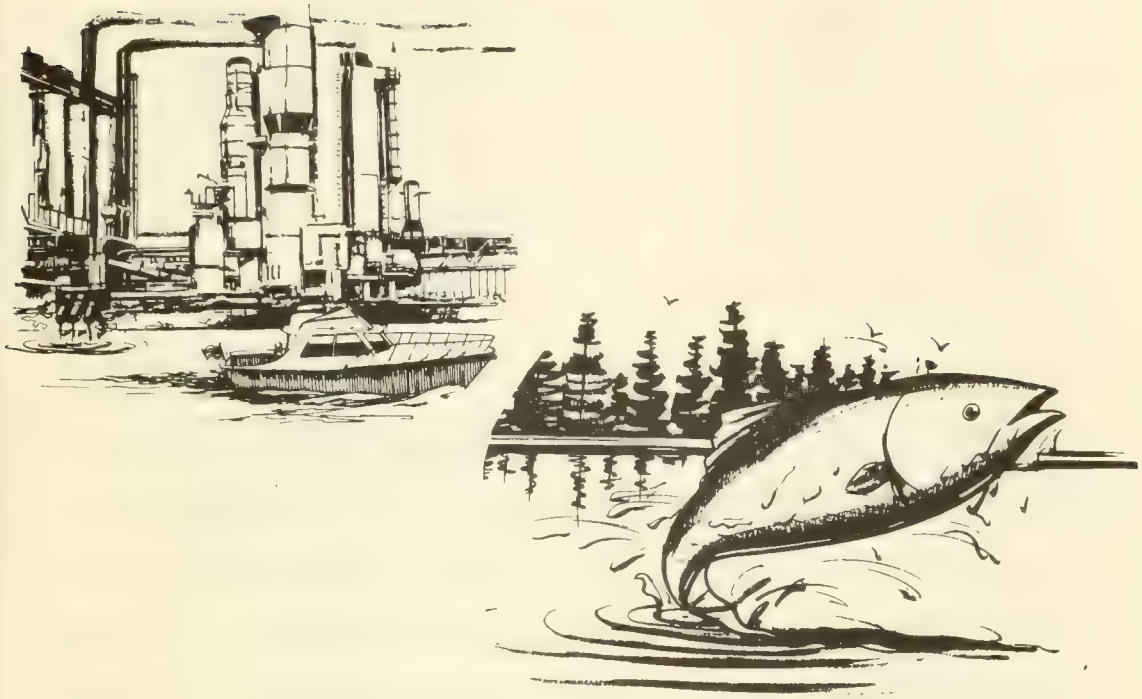
Chapter 7

SUMMARY



The estuarine zone is an ecosystem. That is, it is an environment of land, water, and air inhabited by plants and animals that have specific relationships to each other. This particular ecosystem is the interface between land and ocean, and one of its key components is human society.

The social and economic environment that forms human society must be regulated by man-made laws intended to provide justice to each individual and part of the socioeconomic environment. The biological

and physical environment of the estuarine zone, in contrast, obeys natural laws which are equally complex and less flexible than man-made laws. The welfare of American society now demands that man-made laws be extended to regulate the impact of man on the biophysical environment so that the national estuarine zone can be preserved, developed, and used for the continuing benefit of the citizens of the United States.

To apply man-made laws and regulations to the natural estuarine environment, it is necessary first to understand what natural conditions govern that environment, and then to understand how the socioeconomic and biophysical environments affect each other. Only then can there be developed an institutional environment which can effectively weld all three environments into one smoothly functioning self-sustaining ecosystem.

SECTION 1. THE BIOPHYSICAL ENVIRONMENT

Laws regulating the socioeconomic environment exist at several levels of governmental authority. The Constitution presents general guiding principles, State constitutions operate within this framework while establishing a more detailed body of law designed to satisfy the needs of the statewide socioeconomic environment, and local ordinances regulate in detail the activities carried out in specific locations.

The biophysical environment is also subject to a hierarchy of laws, regulations, and conditions. The general guiding principles are those fundamental natural laws which govern all life on the earth; at the interfacial zone between land and sea the effects of these laws appear as universal dominating environmental factors. The structure of the coastline, formed and modified in obedience to these general conditions, imposes a second level of natural law which exerts its primary effects on water movement in the estuarine zone; and, within each structural form exists a host of organisms living according to specific natural ordinances which govern their relationships.

DOMINATING ENVIRONMENTAL FACTORS

The natural estuarine environment is based on the conversion of radiant solar energy into other forms of energy with the assistance of the mechanical effects of gravitational energy. This conversion

is accomplished by an intricate array of prey--predator relationships among living organisms, from the microscopic plants and animals which convert solar energy directly and are eaten by other organisms, to the fish and wildlife which are the ultimate life forms in the manless estuarine environment.

Solar radiation and gravitational forces control the natural environment through a complex series of mechanisms. In the estuarine zone this control exhibits itself through seven major environmental factors tnat exist throughout the estuarine zone.

(1) Continental Shelf. The submerged land next to the continent slopes gently to a depth of about 600 feet, then it drops more rapidly to form the deep ocean basins. This fringe of slightly sloping submerged land, which along much of the Atlantic and Gulf coasts would appear quite flat to the naked eye, is called the "continental shelf;" its width and general configuration along the U.S. coastline affects the force with which ocean waves strike the shore and consequently the manner and degree of shoreline erosion and accretion.

(2) Ocean Currents. The major ocean currents passing near or impinging on the continent exert strong, if subtle, effects on the estuarine zone through their temperatures, which affect continental land temperatures,

and through their nutrients, which govern the nature and productivity of offshore and estuarine fisheries. The cold Labrador Current water from Maine to Virginia, warm Gulf Stream water along the South Atlantic and Gulf coasts, and the California Current along the Pacific coast all have noticeable effects on coastal land and water.

(3) Coastline Slope. The configuration of the coastline itself, even though subject to additional molding by the flow of rivers to the sea, is closely related to the shape and structure of the continental shelf. A wide continental shelf is generally associated with lowland next to the coast, while a narrow shelf is associated with mountainous terrain. These associations throughout the estuarine zone of the United States have produced estuarine systems characteristic of particular regions. Glaciation in New England, Washington, and Alaska; old mountain ranges and a sedimentary coastal plain from New Jersey to Texas, and the young, steep ranges of the Pacific coast are all continental features having different impacts on the estuarine zone.

(4) River Flow. The estuarine zone is also shaped through erosion and sediment transport by fresh water making its way to the sea. All along the coastlines are streams and

rivers carrying water from land runoff to the sea. These waterways range from the Mississippi River, which drains 41 percent of the conterminous land mass of the United States, down to tiny trickles across a beach. The volumes of water and sediment moved reflect not only the total amount of precipitation and its annual cycle, but also the sizes and slopes of drainage basins and the types of soil over which the rivers flow.

(5) Sedimentation. The general outlines of many estuaries, lagoons, and embayments in the estuarine zone were formed by erosion from land runoff during the last ice age when sea levels were much lower than they are now. As the sea level rose, the drowned river mouths became zones of mixing, sediment deposition, and erosion where the rivers and tidal currents met. These erosion and sedimentation processes molded the estuarine zone into its present shape and continue to change it.

(6) Climate. Solar energy striking the earth sets up complex cycles of water and energy flow from the oceans to the sky and the land and back again. That part of the energy cycle occurring in the atmosphere gives rise to the various combinations of weather phenomena which make up local climates. Land, sea, and sky are mutually dependent in producing specific climates, and the great ocean currents

play their indirect roles in modifying the climates of the estuarine zone.

(7) Tide. The tide stands alone as a controlling force and symbol of the estuarine environment. The combination of tidal action and river flow gives rise to that unique phenomenon called an "estuarine circulation pattern," which means the fresh water flows in one direction in one layer and the salt water flows in the opposite direction in another layer with various degrees of mixing at the interface between them. This type of circulation pattern is of great importance in some of the estuaries along the Atlantic and Gulf coasts, and to a large extent governs the capacity of such estuaries to rid themselves of waste materials.

THE BIOPHYSICAL ESTUARINE REGIONS

Each estuarine system along the coastline is affected to some extent by all of these dominating environmental factors. In some cases the dominance of one particular factor is readily apparent. It is much more often the case that the competing environmental factors are so evenly balanced that none can be said to dominate and the estuarine zone appears to be composed of a bewildering variety of unique systems.

Yet, the dominating environmental factors listed above form a set of natural guiding principles which govern the general characteristics of the estuarine zone of the United States, and the occurrence of various combinations of these environmental factors permits the grouping of the national estuarine system into 10 geographical zones, each governed by a different combination of environmental conditions.

Characteristics of the Biophysical Regions

North Atlantic Estuarine Region: Canadian border to Cape Cod.

Cool, fertile waters with a large tidal range strike a steep, indented coast with deep water close inshore, but protected from the full force of the ocean waves by a wide continental shelf. Moderate precipitation with heavy snowfall leads to heavy spring river runoff which dominates local circulation. Natural erosion and sedimentation are not severe problems, and the evolution of drowned river valley estuaries is in an early stage in this region.

Middle Atlantic Estuarine Region: Cape Cod to Cape Hatteras, exclusive of Chesapeake Bay.

A wide, gently sloping continental shelf with a smooth shoreline is cut by the entrances of several major river systems carrying moderate amounts of sediments. The same cool, fertile waters as in the North Atlantic estuarine region wash this coastline but with a smaller tidal range. The evolution of drowned river valleys

into coastal marshes is in a secondary stage in the larger estuarine systems, with sand spits and barrier islands forming.

Chesapeake Bay Estuarine Region: All of the Chesapeake Bay system from Cape Charles and Cape Henry Island.

Isolation from direct oceanic effects in much of the greatly branched system, the many subsystems with major river flows, and the reduced concentration of the ocean salt throughout the Bay and its tributaries make this a unique estuarine system. This is a drowned river valley with numerous similar tributary systems in various stages of evolution.

South Atlantic Estuarine Region: Cape Hatteras to Fort Lauderdale, Florida, (about 26^{o} North Latitude).

The generally wide continental shelf is brushed by the warm waters of the well-defined Gulf Stream. The low-lying coastal plain terminates in barrier islands and marshes in which large amounts of sediments are being continually deposited by moderate-sized rivers fed by heavy summer rainfall. Many of the drowned river valley estuaries have evolved all the way to coastal marshes. Tidal ranges are small to moderate, depending on local conditions.

Carribean Estuarine Region: Fort Lauderdale to Cape Romano (the Florida peninsula south of 26^{o} North Latitude), plus Puerto Rico and the Virgin Islands.

High temperatures, heavy rainfall, and warm ocean currents along practically nonexistent continental shelves result in tropical

estuarine environments throughout this region. Coral reefs and mangrove swamps are the typical coastal features of south Florida, while the islands are mountainous and are fringed with coral reefs and beaches. Tidal ranges are small.

Gulf Coast Estuarine Region: Cape Romano to the Mexican border.

A wide continental shelf extends all the way around this large embayment, in which warm tropical waters are moved gently by weak currents and small tidal ranges. Heavy rainfall over most of the area brings sediments from the broad coastal plain to be deposited in the estuarine zone. Most of the drowned river valleys have evolved to a point intermediate between those of the Middle and South Atlantic Regions--barrier islands are extensive and have large shallow bays behind them.

The Mississippi, carrying drainage from 41 percent of the conterminous land mass of the United States, forms one of the major deltas of the world and is unique among the estuarine systems of the United States, both in its size and in the extent to which it has built out over the continental shelf.

Pacific Southwest Estuarine Region: Mexican border to Cape Mendocino.

Because of the narrow continental shelf, peridoc upwelling of deep water close inshore as winds force the California current offshore

brings cool, fertile water near the coast for several months of the year. The coastline has a typical beach and bluff configuration with only a few shallow embayments and the unique earthquake-born valley of San Francisco Bay, which, in the delta formed by the confluence of the San Joaquin and Sacramento Rivers, shows what erosion and sedimentation might have done along the southwest coast if rainfall were greater in that area of easily erodable mountains.

Pacific Northwest Estuarine Region: Cape Mendocino to the Canadian border.

The continental shelf and coastal configurations are similar to those of the Pacific Southwest, but ocean water temperatures are lower here; the movement of the California current away from the coast is not as pronounced, and heavier rainfall has resulted in some major rivers cutting through the coastal mountains to form deeply embayed estuarine systems. Extensive erosion and sedimentation have caused wide tidal flats, bars, and shoals to be typical of these systems.

The straits of Juan de Fuca and Puget Sound, which were glacier-formed, do not have as severe sedimentation as exists along the ocean coast, and have retained much of their original configuration.

Alaska Estuarine Region: All of Alaska including the Aleutian and Bering Sea Islands.

The dominant factors in this region are temperature and precipitation. Water temperatures are near freezing, and much of the precipitation falls as snow. The continental shelf is wide all through the region, and tide ranges are very large. The southeast and south coasts have active glaciation and consist primarily of glacier-cut embayments and fjords; the west and north coasts are much flatter and have been modified to some extent by sediments eroded from the interior, including glacial silt, and by the grinding action of pack ice during winter.

Pacific Islands Region: The Hawaiian Islands, American Samoa, and Guam.

This region consists of tropical ocean islands of volcanic origin. Dominating factors are lack of a continental shelf, full exposure to oceanic conditions, and pleasantly warm temperatures. Coral reefs and beach and bluff configurations are typical.

THE LAND AND THE WATER

Within the general domination of broad-scale environmental factors are smaller scale governing conditions that, through their effects on water movement and circulation, determine what kind of local environment can exist in a particular estuarine system.

THE LAND

The shape of the land along the land-sea interface goes far toward determining what water movement and circulation patterns exist in particular local areas and, consequently, how fast a particular estuarine system will rid itself of pollutants. Within the general compass of the estuarine regions discussed in the preceding section there are different structural types which define patterns of water movement typical of particular structures, no matter what the external environment may be.

Alaska presents the greatest variety of estuarine form and structure of any of the estuarine regions. Nearly all kinds of systems typical of other regions are found there. In addition, Alaska has the only glaciated coast and most of the fjords found in the United States.

Characteristic of the North Atlantic region is a very irregular, hilly coastline with deep water close inshore and long, narrow embayments with open access to the sea. Estuarine systems within the Chesapeake Bay region consist of a group of branched rivers entering the Chesapeake Bay itself, which is in turn the former valley of the Susquehanna River.

In the Middle Atlantic region the estuarine zone consists primarily of a few large drowned river valley embayments (e.g., New York Harbor, Delaware Bay, Narragansett Bay) and some small marsh and

barrier beach systems receiving only coastal fresh-water runoff. The estuarine zone of the Gulf region, on the other hand, consists mainly of moderate-sized embayments with barrier beaches and extensive marshes, but receiving river flow from upland drainage areas and representing an intermediate state in the evolution of drowned river valleys into coastal marshes.

The South Atlantic region has two dominant types of estuarine structure. From Cape Hatteras to about Jacksonville, Florida, there is a general input of upland river drainage to the estuarine zone and the estuarine systems are typical drowned river valleys in the later stages of evolution represented by barrier beaches or coastal marshes backed by extensive swamps. South of Jacksonville fresh-water runoff comes primarily from local coastal drainage, and there are uniform and extensive barrier island beaches with long narrow embayments behind them having continuous but generally narrow strips of marsh along the embayments. This structure fades into the extensive swamplands of the Everglades farther down the Florida Peninsula.

Both the Pacific Northwest and Pacific Southwest regions have few estuaries. The estuarine systems of the Northwest Pacific Region tend to be the mouths of rivers which have cut their way through coastal mountain ranges, either of their own accord or aided by glaciers as in the case of Puget Sound. Shallow coastal embayments with little and sporadic river flow are characteristic of the few

estuarine systems of the Southwest, except for San Francisco Bay, which receives fresh water runoff from much of central California.

Estuarine systems of the islands, both Atlantic and Pacific, are few and consist mostly of embayments without major river inflows.

The estuarine zone can be classified according to its local morphology into ten major categories, several of which exist in each of the estuarine biophysical regions. Within each of these categories, the similarities in structure reflect similarities in water movement, water quality, and ecology which make it possible to apply lessons learned in managing an estuarine system in one region to similar estuarine systems in other regions. The morphological categories are:

1.1 Smooth shoreline without inlets

1.2 Smooth shoreline with inlets

1.3 Smooth shoreline with small embayments

2.1 Indented shoreline without islands

2.2 Indented shoreline with islands

3 Marshy shoreline

4 Unrestricted river entrance

5.1 Embayment with only coastal drainage

5.2 Embayment with continuous upland river inflow

6 Fjord

Unrestricted river entrances and embayments dominate the estuarine zone and are rather evenly distributed throughout all the regions, with the common type of estuarine system being a coastal embayment with drainage from only the local coastal area. Many of these latter embayments have large marsh areas, but the Middle Atlantic, South Atlantic, and Gulf are the regions in which marshes are the predominant feature in some parts of the estuarine zone.

THE WATER

The unique nature of water movement and circulation patterns in the estuarine zone are the result of the meeting and mixing of fresh river water and salty ocean water of slightly greater density under the oscillating influence of the tide. There may be additional complicating factors such as temperature and wind action, but the resulting circulation nearly always reflects the interaction of river flow and estuary shape with the tidal flow of the ocean water. General water movement patterns are predictable for each category of estuarine shape.

It is where moderately large rivers and streams meet the sea that the unique estuarine circulation patterns occur most frequently. Large fresh water flows in well-defined channels tend to slide over the top of the denser sea water without rapid mixing. Water movement in such cases exhibits various degrees of stritification.

With wider channels, smaller river flows, and greater tidal ranges. more mixing occurs and other forces come into play. Embayment shape, bottom configuration and material, and the effects of the Earth's rotation all may play a role. In some estuarine systems of this type, the degree of stratification may change with changes in river flow, temperature, wind, or other transient conditions.

Estuarine water quality is the product of both land and water. From the land, erosion and solution in river water bring suspended and dissolved minerals, while decaying vegetation adds dissolved salts, but negligible quantities of organic matter.

In the estuarine zone these two different solutions meet and mix. Salt concentrations range from that of the oceans to the almost unmeasurable amounts present in some rivers. Where little stratification exists, sea salt dominates mineral concentrations in estuarine waters; in stratified systems, however, the small amounts of minerals entering in the fresh water may be as important in some parts of the estuarine zone as the much larger concentrations from the sea are in others.

THE LIFE

The governance of the dominating environmental factors, as modified by estuarine shape and water quality, result in an input of energy into individual estuarine systems, and it is in the variety and diversity of estuarine life that the input of energy to the estuarine

zone finds ultimate expression. Whether energy comes directly, as in solar radiation stimulating photosynthesis, or whether it comes indirectly, as with tidal flows or wind and rain pounding on the shoreline, its absorption and conversion to other forms of energy (such as food) are essential steps in the continuation of life in the water, in the marshes, and on the land.

Energy input from gravitational forces, as illustrated by tidal action and river flow, depends primarily on local or regional conditions, but direct energy input from solar radiation depends largely on latitude, the tropics receiving much more energy per acre than the arctic. The relative amounts of energy entering an estuarine system govern the kinds of life found there, and natural ecosystems show systematic variations related to the sources and amounts of energy received.

Estuarine zones with strong mechanical energy inputs from waves, currents, tides, or river flows develop similar ecosystems no matter whether in the tropics or the arctic. Where, however, such energy inputs do not dominate the input of radiant solar energy, natural communities develop compositions typical of Tropical, Temperate, or Artic latitudes.

Tropical systems are subject to unvarying warm termperatures; light energy input is both greater and more regular than in other latitudes. Within this general group there are the sparse populations along coasts with deep clear water close inshore; the teeming

and colorful populations of coral reefs; and the mangroves and the submerged grasslands associated with shallow, nutrient-laden water. Only the southern part of Florida and the islands are of this type.

Arctic systems are subject to wide fluctuations of sunlight and temperature but ice is the key factor. Ecological systems develop in, on, and under the ice and in the fjords associated with glaciers. Only a small part of Alaska includes estuarine systems of this type.

Temperate systems are subject to moderate solar energy inputs, temperatures which change regularly with the seasons, and generally larger tide ranges and more wave action than either tropic or arctic systems. Most of the estuarine systems of the United States lie in the temperate zone, and the balancing of solar energy input against mechanical energy input in this zone leads to a great variety of ecosystem types, even within small geographic areas.

The grouping of ecosystems outlined here describes a limited range of recurring variation of chemical and physical properties to which certain forms of life have adapted and on which they are now dependent.

The basic environmental needs for all living plants and animals in such zones are zones of salinity consistently fluctuating over a limited range of concentration; solar energy; water temperature variation; water quality and nutrients favorable to their

propagation, growth, and survival; and, for some life forms, bottom conditions suitable to their unique needs.

The dependence of fish and shellfish on the estuarine zone is governed by particular environmental requirements for reproduction, protection, food supply, or a combination of these. Estuarine dependent species are of three types:

1. Species Restricted to Estuaries

Among the relatively few species of fish and shellfish that complete their entire life cycle in the estuarine zone is the Atlantic (American) oyster. It will die after long exposure to freshwater although it can stand limited periods of such exposure and can thrive in relatively high salinity water. The spotted sea trout occupies the estuary for all its life purposes and only occasionally leaves the estuary under unusual extremes of salinity and temperature.

2. Anadromous and Catadromous Species

Anadromous species pass through the estuarine zone on their journey from the sea to the freshwater environment where they spawn. Some species, such as the Pacific salmon, die after spawning and others, such as the striped bass, live to return to the estuarine zone and

the sea. The young of all anadromous species spend varying periods of time in the freshwater areas where they were spawned, but all eventually migrate to the estuaries and then the sea.

There are few truly catadromous species that mature in the fresh or brackish water environments, and then migrate to higher salinity waters of the estuary of the adjacent sea to spawn. The American eel and the Blue crab are examples of this type.

3. Migratory Estuarine Species

The great majority of estuarine dependent species fall under this classification. Some use the brackish and freshwater areas of the estuarine zone for reproduction; some as a source of food; some for shelter, either as adults or young; and some for all these reasons. They all have in common the basic need for both estuarine and ocean environments at some point in their life cycle. This group includes the great majority of fish and shellfish of direct importance to man, such as shrimp, menhaden, flounders, and red drum.

Estuarine wildlife can be classified into four categories: (1) fur bearing animals, (2) game waterfowl, (3) ornamental shore birds, and (4) the common wildlife that can tolerate human presence.

The primary fur bearers are the fur seal in Alaska, nutria in the South Atlantic and Gulf States, the common eastern muskrat in New Jersey, the Virginia muskrat in the Central Atlantic States, and the Louisiana muskrat in Alabama, Mississippi, Louisiana, and Texas. Secondary in importance are the raccoon, mink, and otter.

The dependence of waterfowl on the estuarine zone is both complex and incompletely understood. The primary sport species, such as mallards and canvasbacks, have been successfully adapted to man-made changes in their environment, particularly those changes not affecting the nesting sites.

The ornamental shore and sea birds are a particularly aesthetic attraction among the national fauna. These birds are generally more dependent upon estuarine conditions than the more mobile waterfowl and, in addition, have demonstrated a considerably greater sensitivity to the overall encroachment of man. These birds include whooping cranes, pelicans, bald eagles, egrets, ibis, and many others.

GOVERNING SUBDIVISIONS OF THE BIOPHYSICAL ENVIRONMENT

Solar energy and gravitational energy are the basis for everything that happens naturally in the estuarine zone. This discussion of the biophysical environment has been concerned primarily with the environmental conditions surrounding the transformation of these

energies into forms useful in living processes and exploitable by man. Three different sets of subdivisions of the biophysical environment were used in this discussion.

Differences in the external environment divided the estuarine zone of the United States naturally into ten geographic regions, each subject to a particular governing combination of the external influences of tide, ocean currents, wave action, sedimentation, and climate. This subdivision into estuarine biophysical regions gave broad ranges of conditions in each region, but the importance of local coastal conditions in governing energy flows via water movement paved the way for a subdivision of the estuarine zone according to ten morphological groups having similarities in water movement, circulation, and the ability to rid themselves of wastes.

A subdivision according to ecological communities was also based primarily on geographical location, but again coastal conditions made it necessary to identify small ecosystems governed by specific local conditions within each of the major groupings.

SECTION 2. THE SOCIOECONOMIC ENVIRONMENT

The socioeconomic environment of the estuarine zone is the direct result of its value as a means of sustenance, a place to live, a source of enjoyment, and a route of transportation. The laws regulating man's activities in this zone are historically intended to protect and serve individual and group interest in dealing with each other. Only recently has it become apparent that the laws protecting man from himself must be extended to protect the natural environment from man.

This extension of the institutional environment must recognize not only the realities of how the biophysical environment operates, but it must also recognize the need of human society for the estuarine zone and its value to civilization both as an essential part of his ecosystem and as an exploitable resource.

POPULATION AND INDUSTRIAL DEVELOPMENT IN THE ESTUARINE ZONE

The importance of the estuarine zone of the United States to the national community is shown most clearly by the numbers of people that use it. Population concentration in the coastal counties began when the first European colonist arrived. This concentration brought about the development of a corresponding amount of manufacturing industry in the estuarine zone, while the great harbors gave the estuarine zone its dominating position as the commercial center of the Nation.

Long before the settlement of Plymouth, British, French, and Spanish fishermen were exploring the North Atlantic fishery resources including those in the Gulf of Maine and along Georges Bank; after colonization of New England, the fisheries were the sustaining industry that provided the economic foundation for growth and development. The estuaries were also the entry portal for the immigrants that came to this Nation looking for the land of opportunity.

As the population grew, the relative importance of the fishery progressively declined as economic growth in other industries outstripped the demand for seafood as a staple diet item. The growth of industrial and population centers in the estuarine zone closely paralleled the growth of the rest of the Nation, with the estuarine zone becoming relatively more important in international commerce and less important in agricultural food production than the interior of the country.

The coastal counties contain only 15 percent of the land area of the United States, but within this area is concentrated 33 percent of the Nation's population, with about four-fifths of it living in primarily urban areas which form about ten percent of the total estuarine zone area. Another 13 percent of the estuarine land area is farmland, but this accounts for only four percent of the total agricultural land of the Nation. The estuarine zone, then, is nearly twice as densely populated as the rest of the country,

and supports only one-fourth as much agriculture per unit area.

In those regions lying between Cape Hatteras, N. C., and Canada as well as in the Pacific Southwest, over 90 percent of the population lives in urban areas; over much of the Atlantic estuarine zone stretches the great northeastern megalopolis with population densities averaging over 1,000 persons per square mile. The remainder of the estuarine zone of the United States exhibits a pattern of major centers of population clustered around natural harbors and separated by stretches of coastline which are either empty and inaccessible or beginning to be sprinkled with private residences and resort communities in the vicinities of population centers.

The coastal counties have within their borders 40 percent of all manufacturing plants in the United States. The mixture of manufacturing types in the estuarine zone is the same as the national composition with only minor exceptions, such as the concentration of the apparel manufacturing industry in the Middle Atlantic Region, particularly in the New York area. Distribution of manufacturing types among the biophysical regions shows regional differences related to historical development as well as raw material and market availability.

Over half of all plants in the coastal counties and one-fifth of all manufacturing plants in the United States are located in the Middle

Atlantic biophysical region, which was the historical center of the Nation's industrial growth and is still one of the major market areas. The Pacific Southwest is the major industrial center of the Pacific coast and is developed as intensively as the Middle Atlantic region. Some industrial development in other Regions tends to follow historical or present raw material availability. Leather product plants are clustered in the North Atlantic region, and lumber manufacturing plants are most plentiful in the Pacific Northwest. Food processing plants, however, follow closely the distribution of population.

While much of the industrial development located in coastal counties affects the estuarine zone indirectly through use of adjacent land, some of the water-using industries have an impact on the estuarine zone far beyond their numbers. The paper, chemical, petroleum, and primary metals industries are the major water users among manufacturing establishments and are distributed universally throughout the estuarine zone.

USE OF THE ESTUARINE ZONE

Many of the uses catalogued in this report occur only because the historical growth of the country makes the estuarine zone the place where the people and the industry are. Only commercial navigation and commercial fishing are uses which are primarily associated with the estuarine zone rather than other parts of man's

environment. Uses such as water supply, waste disposal, and recreation are associated with civilization wherever it exists; in the estuarine zone they may have different values, different emphasis, or different impact on the biophysical environment.

The great unique use of the estuarine zone, which makes it of primary importance to man and his civilization, is its place in the life cycle of many animals which aid in converting solar energy into more usable forms. While no life form can be singled out as irreplaceable, the kinds of life which need the estuarine zone to survive represent essential links in the energy conversion chain upon which man depends for survival. Many of the human uses of the estuarine zone depend directly or indirectly on the existence of the estuarine zone as a healthy habitat.

FISHING

The important fish species are those sought by either the sports fisherman or the commercial fisherman. Practically all of the sports fish species are dependent upon the estuarine zone for one or more phases of their life development, and approximately 65 percent of all commercial fish species are estuarine-dependent.

In 1967 United States fishermen received $438 million dollars for approximately 4.06 billion pounds of commercial fish and shellfish. It has been estimated that two-thirds of the total value, or approximately $300 million dollars, can be considered for

estuarine-dependent species. This is a conservative estimate of the direct value derived from the estuarine fishery for it does not include the value of fish harvested by foreign vessels off the United States coast. Five of the six leading species by weight, representing over one-half of the United States commercial fish tonnage in 1967, are estuarine-dependent.

RECREATION

The demand for outdoor recreation has increased significantly over the past decade. The trend toward higher personal income and more leisure time has made it possible for a greater percentage of the populace to seek new outlets. Companies manufacturing equipment for outdoor recreation have sprung up by the hundreds.

The advertising industry has campaigned vigorously to sell the public on the need for recreation, and service facilities to support the recreationalist are blossoming in all parts of the country.

There are a wide variety of land and water recreational activities available in the estuarine zone and many estuarine systems are intensively used for recreational pursuits. The unique combination of available resources in close proximity to large population centers offers an unparalleled recreational opportunity for many people who could not afford to travel far from their homes.

Each type of recreational activity has a certain sensitivity to the quality of the environment in which the activity takes place.

Clusters of activities that require similar environmental conditions but differ in environmental quality needs can be grouped as follows: 1) swimming and associated shore activities, including picnicing and camping; 2) sports fishing from shore or small boat; 3) boat-centered activities, such as cruising or water skiing; and 4) aesthetic appreciation of the total environment.

The Nation's estuaries provide the physical, social, and economic conditions required for an effective system of water terminals serving international trade and coastal shipping. According to a 1966 inventory of ports and terminals by the Maritime Administration, there were 1,626 marine terminal facilities providing deep water berths in 132 ports on the Atlantic, Gulf, and Pacific coasts. The significance of these ports and terminal facilities is indicated by the 1965 statistics which show that these ports handled 346,315,000 tons of foreign trade cargo which was 78 percent of the U. S. foreign trade total. In addition, the port facilities handled 332.1 million tons in coastal cargo and $288.2 million tons in local shipping.

The estuarine ports also serve as essential elements of the national defense system. The deep water terminals exert a significant influence on the location of defense installations as well as of the industrial complexes necessary for logistical support of the defense effort. A direct indication of the use of estuaries by naval vessels is the total number of ships in commission. During

the Fiscal Year 1967 this number was 931 with a planned increase to 960 in the Fiscal Year 1969.

The use of the harbors for waterborne transportation is competitive in that it may cause other uses to be foregone. Heavy ship traffic interferes with pleasure boating and related activities (Figure IV.55). Maintenance of the ship channels may alter the ecology and the surface area occupied by the large vessels may well interfere with safe pleasure boating.

Water transportation is not the only type of transportation consideration for estuaries. Since a major percentage of large cities are located on estuarine systems, there is considerable pressure to develop fill areas for airports which then utilize the long overwater approaches to keep the jet noise away from developed areas. The water areas offer a barrier to land travel that must be overcome with causeways or bridge type structures which can interfere with navigation or cause habitat damage. On the other hand, peripheral roads offer some of the more scenic routes available and are frequently the only undeveloped are on which roads can be built.

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

The water in the estuary can serve as a source of both domestic and industrial water supply; but utilization of estuarine water for domestic supply is very limited at the present time. Normally

the brackish water is unpotable and treatment costs to render it potable are extremely high. The brackish estuarine water is also a poor source for industrial process water. Here again a high degree of purity is normally required in the process water and the cost of removing the dissolved salts is prohibitive.

Estuarine waters are used extensively, however, as a source of industrial cooling water. For this use the most important considerations are the quantity and the ambient temperature. Water temperatures are generally well below the maximum for economical cooling, and since the ocean is connected to one side of the estuary, the quantity is no problem. Cooling water is required by both the manufacturing industry and electric power generation plants; the greatest use is in the thermal electric plants.

The distribution of cooling water use parallels population and industrial development in the coastal counties, even though electrical power can be transported economically over many miles. The greatest concentrations of cooling water use are in the Middle Atlantic and Pacific Southwest Regions; fortunately these regions both have moderate water temperatures which make possible efficient

use of the available cooling water.

There are, however, 47 nuclear power plants built or scheduled for completion by 1976. All of these are in the megawatt range, with a combined capacity of nearly 35,000 megawatts of electrical power. While the bulk of these will be in the cooler parts of the Nation, 12 will be in the South Atlantic, Gulf, and Caribbean Regions where water temperatures are high, greater volumes must be used to achieve proper cooling, and the increase in water temperature through the power plant may be sufficient to cause environmental damage.

WASTE DISPOSAL

The concentration of population and industrial development in the estuarine zone has led naturally to the use of estuarine waters for removal of the waste materials of man's civilization from his immediate vicinity. It is unlikely that cities were built on the coastline with any conscious consideration of the use of the estuarine environment for waste disposal, yet it has happened that this use has become one of the major uses of estuarine waters and the associated land. Virtually all of the cities and industries in the coastal counties dispose of wastes either directly or indirectly into the estuarine zone.

Liquid waste discharges to estuarine systems include domestic waste products, industrial waste materials of all degrees of

chemical complexity and sophistication, used cooling water with its thermal load, and storm runoff. These wastes affect the estuarine environment in different ways and can eliminate other uses.

Liquid wastes are not the only concern. The use of the estuarine shoreline for refuse dumps and land fills results in considerable debris getting into the water; water leaching through these dumps has a pollutional impact on the estuarine water. Spoil disposal from dredging activities is another form of solid waste material that contributes to estuarine degradation, and solid materials entering the estuary in the form of debris from storm runoff can be significant in terms of damaging beneficial uses.

Waste disposal is a highly significant and universal use of the estuarine resource and it is likely to remain so. Along with the many other socioeconomic uses of the estuarine environment, it must be managed so that it does not damage the biophysical environment.

EXPLOITATION OF MINERAL RESOURCES

Minerals within the water, on the bottom, and under the bottom are a valuable part of the estuarine resource and are being exploited widely.

Sub-bottom mining operations are limited to the recovery of sulfur, petroleum, and natural gas, with the major operations occurring in

Louisiana, Texas, California, and Alaska. These operations exist both in the estuaries and out on the continental shelves with the governing criterion for location being the location of reserves.

Recovery of minerals from submerged estuarine zone bottoms by surface mining, i.e., dredging, is primarily directed toward sand, gravel, and oyster shell production. Sand and gravel operations are universal throughout coastal areas wherever suitable deposits and a market exist.

Oyster shell is an extremely useful construction material in the Gulf of Mexico biophysical Region. Twenty of the twnety-two million tons of annual U. S. production are in the Gulf States with Texas and Louisiana producing the vast majority of it.

Phosphate rock is an important estuarine mineral resource; about 75 percent of the total U. S. production is in the estuarine zone of Florida and North Carolina, particularly around Tampa Bay and Pamlico Sound.

AQUACULTURE

The great fish and shellfish resources of United States coastal waters have adequately supplied the seafood demands of the increasing population for over three hundred years. Now, however, the demands for some products is so great that the normal fishing grounds and fisheries are in great danger of being exhausted, both from overfishing

and from the indirect effects of man's encroachment into the estuarine environment. To supply future needs of some fish products new approaches toward commercial fishing are needed, both in harvesting the natural growth and in controlling the entire fishery. Aquaculture is defined as the rearing of aquatic organisms, both plants and animals, under controlled conditions using the techniques of plant and animal husbandry. It involves a vareity of operations, some that are highly sophisticated where man exercises control over the principal environmental factors affecting the cultured species, and others that are very simple with only minimal control of manipulation of the habitat and the cultured animal.

SHORELINE DEVELOPMENT

The use or development of estuarine water either governs or depends on land or shoreline use.

Commercial development of the shoreline includes loading terminals, docks and shipyards, airports, industrial plants, and the smaller municipal and local piers. Recreational facilities include marinas, beaches, parks, fishing piers, and vacation cottages, motels, and hotels. Although the motels and hotels are a commercial venture, their prime purpose is to support the recreationist. Residential development of waterfront property in many communities places on the shoreline intensive housing development accompanied by boat docks,

fishing and swimming piers, and private beaches. Commercial and personal transportation requires airports, highways, and commercial port facilities.

Structures built to protect or conserve the shoreline include bulkheads to hold the shore in place, dikes to prevent flooding and to extend reclaimed land, jetties to provide a protective barrier between the sea and ship channels, and groins along beach areas to control sand movement.

THE SOCIAL AND ECONOMIC VALUES OF ESTUARINE USE

All uses have value, both individually and as part of the development and use of the entire estuarine resource for the benefit of the present and future national community. The importance and total value of any estuarine system lie not in the measure of economic value for any particular use, but in multiplicity of use related to the needs of people who live there or otherwise depend on the estuarine resource.

FISH AND WILDLIFE HABITAT

The value of the estuarine zone as fish and wildlife habitat both depends on and augments its value for other uses, particularly recreation and commercial fishing.

There is, in addition to these, the basic incalculable value of the estuarine habitat as a link in the essential energy-conversion chain which permits man to survive at all.

The trapping of fur bearers in the marshes of the Gulf and Atlantic represents one of the few economic values directly attributable to estuarine habitat. Louisiana is the major producer; in the 1965-1966 season total sales were 4.6 million dollars out of the Nation's 6 million-dollar total.

Commercial Fishing

An entire complex of commerce and industry can rest upon one primary producing industry such as commercial fishing. Each time the basic product changes hands it generates economic activity and gains in value until by the time it reaches the ultimate consumer, its price may be many times what the fisherman was paid for it. The effect of such "value multiplier" factors will be such as to make the actual values of specific commercial fisheries several times the landed values.

Thus, the 438 million dollars received by United States fishermen in 1967 probably represents a total input to estuarine zone economic activity of over one billion dollars; exactly how much it is impossible to say. Case studies assign multiplier values of about

three and four to commercial fishery landing values, but the magnitudes of such multipliers depend on the structure of the local economy as well as on other factors and generalities are likely to be misleading.

The relationship of the estuarine zone and commercial fishing cannot be expressed by any simple economic index. The importance of commercial fishing in the estuarine zone is related economically not only to estuarine habitat, but also to transportation, commerce, food processing, and aquaculture.

Recreation

Each kind of recreational use has its own economic impact. Recreational boating supports a large boatbuilding, marina, and boat repair industry. Sport fishing supports not only a certain part of the boating industries, but also a very specialized industry manufacturing and selling fishing tackle. For example, the 1965 Survey of Fishing and Hunting shows that salt-water anglers spent $800 million dollars in that year. Sightseeing and swimming support motel and restaurant services in the favored areas, as do other overnight recreational activities.

Attempts at the quantification of overall recreational economic values are not yet well developed. The user-day recreation benefits approach has been used in some federal waterway and reservoir projects,

but has been used in the estuarine system only in an analysis of fisheries and recreation in San Francisco Bay. Net benefits for general recreation activities, by this method, range from $0.50 to $1.50 per day. Specific forms of recreation may have higher values.

Applying such a figure to the population of the coastal counties suggests that the value of the recreational resource of the estuarine zone is about 300 million dollars if each person has about five days of recreational use. Such an estimate would include only local use and no multiplier values and might therefore be regarded as minimum value of the entire value of the entire estuarine recreation resource.

The major problems in defining the economic values of recreation in the estuarine zone lie in the facts that recreation itself is not an easily defined commodity nor can it be isolated from other economic activities such as transportation, food and lodging services, and equipment manufacturing.

Commercial Navigation and National Defense

Estimates of the economic value of commercial navigation are based on the direct revenue to the port of handling a ton of cargo, generally $16 to $20. Such estimates lead to a total value of the estuarine resource of $4.7 billion annually for cargo revenues alone, without multiplier values. An additional economic value of $10 billion annually in salaries and wages has been estimated for eleven major ports.

These estimates do not show the impact of commercial navigation on land transportation, shoreline development, or the manufacturing industries. Without the deep, safe harbors commercial navigation could not exist on a large scale, and without commercial navigation the great cities around these harbors would not have developed.

Deep-water harbors are essential elements of the national defense system. Furthermore, the location of these deep-water ports has influenced the location of other defense installations as well as the industrial complexes necessary for the logistical support of the defense effort.

The cost of the national defense effort in the estuarine zone for 1967 is estimated at about $900 million, exclusive of pay and allowances for shore-based Navy and Marine Corps personnel. The economic impact of national defense activity overlaps into all other estuarine zone uses because of the massive payrolls associated with it. This impact is centered in the areas with major defense installations.

Waste Disposal

The waters of the estuarine zone have received wastes from the people and industries on their shores ever since the first cities were founded. The economic benefit in the use of estuarine waters for waste disposal has been fully utilized by nearly all industries and communities in the estuarine zone, and only the tremendous capacity of estuarine waters to absorb and remove waste materials has kept

the estuarine zone from suffering severe damage from such waste discharges.

No overall estimate of the value of this use of the estuarine resource is possible because the level of treatment necessary in any particular case depends on many local factors.

While the use of estuarine waters for waste disposal may not be aesthetically appealing it is an existing estuarine use with which other uses must compete, and it should be considered along with them in the overall economic evaluation of estuarine uses.

Examples of Socioeconomic Environments in the Estuarine Zone

Almost all estuarine systmes have either a multiplicity of uses at the present time or such uses are available in the system. Estuaries presently support such varied uses as military berthing and associated activities, commercial port facilities, shipping channels, industrial uses, commercial fisheries, sport fishing, recreation, wildlife habitat, and purely aesthetic purposes. In most estuaries one or two of the uses predominate while the others take minor roles.

Narragansett Bay is an ideal example of an estuary that has developed in an unbalanced fashion. That is, the economic value of the estuary at the present time is largely assoicated with the industrial, military, and transportation uses of its waters. Other uses are, of course, made of the estuary but their economic significance is

dwarfed by the tremendous magnitude of the military and commercial uses. However, it must be remembered that this economic measure is merely an indicator of the value of the waters and is not in any way related to the right or necessity of polluting such waters in the process of achieving this value. In fact, the only time that such an economic measure would be used would be for comparing one total use of the estuary to another total use. Of course, it is seldom that questions are so broad as to cover either/or propositions for the entire activity. Rather, the questions usually revolve around such things as the benefits to be derived from reducing pollution caused by users of the estuary compared with the costs of achieving the reduction in pollution.

Franklin County, Florida, is dependent upon pollution-free waters in Apalachicola Bay for its economic existence. The unpolluted waters of the Bay provide the seafood caught by local commercial fishermen and processed at shore-based installations. Additional income for the area results from tourism engendered by the Bay's waters.

Both tourism and commercial fishing are prime potential sources of income to any estuarine system. In the case of Apalachicola Bay, these happen to be the major sources of income because of the nature of the estuary and its location which prevent its development as a commercial shipping facility.

The San Diego economy, although heavily dependent upon the military and shipping activities in the Bay, has diversified to the extent that it is no longer completely dependent upon such uses of the Bay. At the same time there has been a growing demand for recreational uses of the Bay. Evidence of the local resident's interest in the Bay for recreation, tourism, and commerical uses can be found in their willingness to invest substantial sums of money in facilities to prevent pollution of the Bay by municipal wastes.

Mission Bay, a separate estuary in the San Diego area, is an example of the recreational potential to be found in an estuarine system. However, this special study points up the fact that the best use of an estuary may not come about naturally. Rather, it shows that a planned development program with adequate investments are necessary to achieve optimal use of an estuary.

Measures of Overall Value and Importance

The discussions of values of individual uses and the case studies of specific estuarine systems present a confusing picture of the relationship of estuarine uses to economic indicators.

Estimates of the direct gross economic benefit of the estuarine zone to the residents of the coastal counties can be made. The estimates of economic activity generated by the presence of Narragansett Bay in Rhode Island give a conservative annual economic benefit of $920

per capita, $420 of this is personal income. Average personal income for all of the coastal counties is, according to Bureau of the Census figures, $500 per capita greater than the average for the remainder of the country. The total economic activity generated by this additional personal income then amounts to about $1,100 per person, using the Narragansett Bay multiplier values.

The total direct economic benefit of the estuarine zone to the residents of the coastal counties is then about 60 billion dollars in terms of additional economic activity stimulated by the presence of estuarine systems. This is not a measure of the total economic activity of the estuarine zone, but only of the "value added" to the total economic activity of the coastal counties by the presence of the estuarine zone.

Such gross means can give only an order-of-magnitude estimate of even the direct economic value of the estuarine zone and cannot possibly reflect either indirect benefits or the social importance of the estuarine zone, much less its ecological value.

Valid criteria for evaluating the importance of the estuarine environment or the value of individual estuarine uses, to a community must, however, go beyond the reach of economic approximation and recognize the fundamental relationship between man and his environment. Wherever there are people the environment will be exploited to satisfy the needs and desires of man and his civilization.

Increasing environmental pressures from demographic and commercial development are paralleled in the same community by the increasing desire for greater recreational use. That these can be compatible is clearly shown by the San Diego Bay example. Such community reactions as in San Diego and in San Francisco demonstrate that, while people need commercial development and use, they want a safe and enjoyable environment at the same time.

SOCIAL AND ECONOMIC TRENDS IN THE ESTUARINE ZONE

At the present time, the major uses of estuaries, in terms of gross monetary return are: military use, shipping, and industrial activities. These uses are, of course, historical and do not necessarily reflect the uses that would be made of the estuary under today's conditions or future conditions, if each use were to compete for the water use at the same time. In other words, historical use has brought about the present use imbalance in many estuarine systems. However, given the opportunity to develop, other uses might attain equal importance economically while contributing important social benefits.

Estuaries at the present time represent underdeveloped natural resources that are important to the socail as well as the economic well-being of the Nation. Based on present trends and demands, there is little doubt that there will be a tremendous need for estuarine uses other than for military, shipping, and industrial uses. That is, if the facilities are available for recreation, sports, or aesthetic

enjoyment, they will be used and used to great advantage from an economic standpoint as well as a social standpoint.

If normal circumstances prevail, the Nation's population and general high standard of living will continue to increase in the coming decades. A moderate estimate projects a doubling of the national population by the turn of the century, with a significant proportion of that growth occuring in urban areas.

The population will be made up of a large proportion of youth and young persons of working ages, with only a moderate increase in the elderly through the end of the century. Personal income will rise dramatically. Estimates of leisure time vary considerably, but all authorities agree that the work week will shorten, from a conservative estimate of 35 hours a week to as little as 20 hours per week. The National Planning Association has projected that in 1990, ten per cent, and in 2000, twenty per cent of the men between the ages of 25 and 54 will be granted a one-year leave every seven years.

Urban and particularly suburban growth will expand greatly both to accommodate the growing population and to provide amenities that it increasingly demands: single family dwellings, recreational areas, transportation facilities, industrial development, and so on. These demands will place rapidly increasing burdens on the Nation's resources and its environment. These burdens, in turn, will tax the ability of decision-makers and the Nation's population to cope with

the complexity and insistence of the problems generated by a post-industrial, urbanized society.

Information provided by this analysis of national population and economic trends gives only the grossest indication of the activities and expected pressures of population and economic activity on all of the Nation's environment. Analysis of these indicators can only provide a general indication of the magnitude of the demands which will be generated by these forces in the near future on the estuarine zone.

SECTION 3: POLLUTION: THE IMPACT OF HUMAN SOCIETY ON THE ESTUARINE ENVIRONMENT

Man has always used the biophysical environment as he needed it for survival and thrown back into it his waste products and anything else he did not need. As long as civilization was limited to small towns and villages the impact of such treatment on the estuarine environment was not noticeable and apparently insignificant with the development of a civilization based on a complex socioeconomic environment, however, his impact on the natural environment has increased until now the most accurate term to express the relationship of man to his biophysical environment is "pollution."

"Pollution" is the degradation of the biophysical environment by man's activities; it is no longer limited to the discharge of sewage and industrial wastes, but now includes direct or indirect damage to the environment by physical, chemical, or biological modification.

Environmental degradation is the result of often minute changes in water quality, water circulation, or other conditions which are part of the biophysical estuarine environment. There are brightly colored or otherwise visible waste materials which have obvious pollutional implications, but by far the deadliest pollutants are those which are invisible and often unsuspected until the damage is done. These pollutants can be found only by the most delicate and sensitive tests and, even then, the presence of some highly dangerous materials or conditions can only be inferred by indirect evidence.

MATERIALS AND CONDITIONS WHICH DEGRADE THE ENVIRONMENT

One of the major constituents of municipal and many industrial wastes is decomposable organic material. Such materials consist primarily of carbohydrates from plants and paper, proteins from animal matter, and miscellaneous fats and oils. The decomposable organics are not necessarily detrimental by themselves but exert a secondary effect by reducing dissolved oxygen in the water. The level of dissolved oxygen is one direct index of the healthiness of the system. High levels are generally indicative of a healthy system which will support a diverse biota and multiple use. The lower the concentration of dissolved oxygen becomes, the sicker the system is, and the less desirable it is for habitat or use.

Another class of materials, primarily organic, that can have considerable impact on the estuarine ecosystem are the flesh-tainting substances. Generally these materials are contained in industrial waste effluents and they result in offensive tastes, odors and colors of fish and shellfish.

The salts of heavy metals are fairly soluble and stable in solution. Consequently, they will persist for extended lengths of time. Many of these are highly toxic to the aquatic biota, and since many marine organisms exhibit the ability to accumulate and concentrate substances

within their cell structure, the presence of these metals in small concentrations can have deleterious effects.

Aquatic life forms require trace amounts of some minerals and vitamins for growth and reproduction. Elimination of such materials from the environment or their reduction below minimum levels can limit the growth and reproduction of some biota. Conversely, an oversupply of all necessary trace mineral salts and vitamins can stimulate growth; providing satisfactory conditions of temperature, salinity, and dissolved oxygen also exist. An oversupply of inorganic nutrient salts, such as those of nitrogen and phosphorus, may be associated with drastic shifts in the composition of the aquatic community.

One of the many unfavorable effects of municipal and some industrial wastes is the contamination of the receiving environment with bacteria, viruses and other organisms of public health significance. Pathogenic organisms, especially those from the intestines of warm blooded animals frequently persist for sufficient periods of time and distance to pose a threat to the health and well-being of unsuspecting water users. Secondary chances of exposure to these organisms exist through the contamination of shellfish which can be harvested for food.

Among the waste products that are frequently introduced into the estuarine environment are some directly toxic to marine organisms.

Toxic materials may exhibit a short catastrophic impact or a more subtle long-term interference with growth and reproduction processes. The end result is to create a biological desert in which no organism can survive. The pesticide group is of particular concern in the estuarine zone. Estuaries are the terminus for most of the major river systems, and as such they tend to concentrate the waterborne materials carried in by the large terrestrial drainage systems. The biological magnification capability of estuarine animals significantly increases the hazard and destructive potential of any contributed pesticides. The ultimate damage is to stress or eliminate parts of the energy conversion chain in the estuarine environment.

The addition of large quantities of heat from industrial cooling water constitutes a form of pollution which must be considered. The entire ecosystem may be stressed by thermal pollution. The amount of damage is dependent on the resulting temperature of the environment and the species composition of the biotic community. The total range of detriments should be carefully considered on an individual case basis before heat is released to the environment. Heat affects the physical properties of water, the rates at which chemical and biological reactions progress, and can kill living organisms.

Man's activities may affect the rate at which the natural balance of inflow, deposition, and outflow is reached by purposely or

or inadvertently upsetting this balance. If upstream erosion is increased due to poor land management practices, the load carried in will increase. Conversely activities along the coast can result in increased shore erosion, removing more sediment than is contributed. The primary pollutional problem from sediment, however, is from increased influx and accelerated deposition. The detrimental effects of sedimentation are reflected in an impairment of uses such as navigation, recreation, and fish propagation.

One of the greatest threats to the estuarine ecosystem is the ever-present chance for a catastrophic spill of oil or other hazardous materials. The large volumes of petroleum and chemical products transported through the estuarine zone by ships, barges, pipelines, tracks, and railroads present a continuing opportunity for accidental bulk spills. The consequences of these spills depend on the amount and type of material released and the characteristics of the receiving water. They may range in magnitude from tragic loss of life to little more than economic loss for the transporter.

The effect any pollutant has on an estuarine environment depends on where it goes, how strong it is, and how rapidly it is assimilated or flushed out of the environment. All of these conditions depend on water movement and circulation patterns which are in turn governed by the relationship of tide and river flow to estuarine shape and size. Physical modifications such as the dredging of new or

domestic sewage, many municipal waste discharges also contain significant amounts of industrial wastes, which may add to the variability and complexity of the wastes discharged. Municipal waste discharges have four important effects on receiving water quality: depletion of dissolved oxygen, and introduction of pathogenic organisms, settleable material, and inorganic nutrients.

Sewage treatment reduces and alters the impact of municipal waste on the environment. Primary treatment with chlorination will remove part of the decomposable organic material, nearly all of the settleable and suspended solids, and almost eliminate the possibility of pathogens in the effluent. Secondary treatment can almost eliminate decomposable organic material, and some special processes can eliminate certain kinds of dissolved salts. About one half the municipal wastes discharges to estuarine waters receive secondary treatment, with the most extensive use of secondary treatment being in the Chesapeake Bay estuarine region.

Associated with the major metropolitan developments are large numbers of industrial complexes with their attendant waste products. Many of these industrial wastes, especially from the chemical industry, are of such a complicated nature that it is difficult both to identify them and to assess their effects on the receiving streams. Only 4000 of the more than 200,000 manufacturing plants in the Coastal States account for 97 percent of the total liquid wastes discharged.

deeper navigation channels, building of causeways of jetties, and even construction of pier bridges can cause subtle changes in water movement that can change the balance of environmental conditions in an estuarine system and result in gradual undesirable changes in the ecosystem in addition to direct habitat damage.

SOURCES OF POLLUTION

Nearly all of man's activities can result in environmental degradation. Pollutants and polluting conditions are very rarely unique to a particular use or specific activity, but may result from man's existence in the estuarine zone as well as his use of it. The major sources of pollution.

(1) Those sources associated with the extent of development of the estuarine zone, including waste discharges from municipalities and industries, and land runoff from these as well as agriculture;

(2) Those sources associated with particular activities of great pollutional significance, specifically dredging and filling, watercraft operation, underwater mining, and heated effluent discharges;

(3) External sources having impact derived through flow regulation and upstream water quality.

Over eight billion gallons of municipal wastes are discharged daily into the waters of the estuarine zone. While most of this volume is

Of the nearly 22 billion gallons of industrial wastes discharge daily, only 29 percent receive any kind of waste treatment.

Intensification of use of the estuarine zone has resulted in many artificial changes being made in the physical structure. Shoreline areas have been filled to create more land area for residential and commercial use; channels have been dredged and maintained to permit safer and better navigation; and harbor facilities have been dredged and bridges and causeways have been built. All of this activity has had impact on the coastal zone ecosystem, but the activities having the most impact on water quality are dredging and filling. The potential for pollution of the system exists in both filling and dredging; both can introduce foreign materials into the water, destroy aquatic habitat, and alter physical circulation patterns.

The primary source of thermal pollution is from industrial cooling water effluents. Power plants are the major users of cooling water in the estuarine zone, and power generation capacity has approximately doubled each decade during this century. The impact of this growth on the estuarine areas is evidenced by the fact that in 1950 22 percent of the power plants were in the coastal zone; it is anticipated that over 30 percent of the plants will be located there in the late 1970's.

Estuarine areas are also very important highways of commerce, and thousands of commercial vessels, foreign and domestic, from ocean

liners to barges, traverse the coastal waterways each year. Added to this are many of the 1,500 Federal vessels and many nearly eight million recreational vessels. All of these watercraft carry people and/or cargo, and are a real or potential pollution source.

Mining from the estuary floor causes alteration of the estuarine shape and water circulation characteristics, with a secondary effect being the turbidity problems associated with material removal. Mining of sand and gravel from the estuarine floor are universal while oyster shell dredging in any great quantity is restricted to the Gulf coast. These operations remove part of the estuarine floor with a concomitant destruction of habitat and life. There are also great amounts of suspended and settleable solids frequently released into the water, from which they are redeposited in other places.

The water quality of estuarine areas is dependent not only on direct waste sources but also on the quality of the inflowing streams and runoff entering the system. Tributary influent quality is generally a good index of the type and intensity of land use surroundings and upstream from estuarine system and can be a major cause of ecological stress within the system. The complex interactions between fresh and salt water may magnify the effects of pollutants carried into the tidal regime, resulting in quality anomalies completely alien to either fresh or oceanic environments.

EXTENT OF POLLUTION EFFECTS

Environmental damage from human activities manifests itself in changes in water quality and in changes in the living communities. Either or both may be caused by any of the kinds of pollution or sources of pollution mentioned earlier. One key to the degree of environmental impact is measurement of alteration in water quality. Extensive data have been collected on a few of the estuaries with the most severe problems, and limited information is available on other estuarine systems to outline the emergence, or document the existence, of water quality problems.

Examples of estuarine systems that show definite documented water quality degradation as a result of human activities are these: Penobscot Bay, Boston Harbor, Moriches Bay, New York Harbor, Raritan Bay, Delaware Estuary, Baltimore Harbor, Potomac River, James River, Charleston Harbor, Savannah River, Biscayne Bay, San Juan Harbor (P.R.), Tampa Bay, Pensacola Bay, Mississippi River, Galveston Bay, Laguna Madre, San Diego Bay, Santa Monica Bay, San Francisco Bay, Columbia River, Puget Sound, Silver Bay (Alaska), and Hilo Harbor (Hawaii).

Pollutional damage to estuarine ecosystems may be sudden and dramatic as fish or other aquatic life forms suddenly dying, or

it may be so gradual as not to be noticed for many years. Many studies of different aspects of estuarine biology have been made, but there are only a few cases in which comprehensive ecological studies have been made of pollutional effects.

All of the 25 estuarine systems listed above also show some ecological damage, but in 38 percent of the estuarine systems of the United States there is not sufficient information to decide whether there is no ecological damage, or whether there is just no easily identifiable pollution problem present.

The complex nature of pollution in the estuarine zone prevents the separation of sources of pollution, kinds of pollution, and types of environmental damage into neat compartments of cause and effect. All of human activities in the estuarine zone can damage the environment and most of them do.

Wherever people live, work, and play in the estuarine zone the demands of their social and economic activities place stresses on the bio-physical environment. These stresses frequently result in degradation of that environment, perhaps not immediately or even in a few years, but nonetheless certain in its devastating final impact.

SECTION 4. USE CONFLICTS AND DAMAGES: MAN'S BATTLE WITH HIMSELF AND NATURE

The consequence of damage to the biophysical environment is loss of use either immediately or at some time in the future. Loss of use, however, may also be associated with the appropriation of part of the estuarine resource for one exclusive use even when no damage to the environment itself occurs.

Institutional management must cope with the problems of responsibility and authority in achieving maximum multiple use of the estuarine resource. Within this comprehensive framework technical management must resolve the problems surrounding conflicts of use, competition for the resources of the estuarine zone, and environmental damage. The primary objective of technical management is to achieve the best possible combination of uses to serve the needs of society while protecting, preserving, and enhancing the biophysical environment for the continuing benefit of present and future generations.

The uses of the estuarine zone grew and changed in consonance with population growth and industrial development. Not until recent years was a concerted attempt made to understand and resolve the conflicts that arose in the competition to use and exploit these land and water resources. During the past three hundred years of growth and industrial expansion with its emphasis on economic growth

and direct monetary gain, large parts of the estuarine zone were pre-empted or usurped to serve the individual needs of commercial enterprises. The net result has been less a conflict in existing uses than an exclusion of some uses.

Nearly all estuarine uses involve both land and water, either directly or indirectly. For example, the construction of a manufacturing plant on the shore of an estuarine system may not involve any direct use of the water (even for waste disposal), yet it limits access by its occupation of the shoreline and so may interfere with other uses. Conversely, the disposal of liquid wastes into the water may make the shoreline unusable for recreation as well as making the water itself unsafe.

The impact of one estuarine use on another may be either "prohibitive" or "restrictive"depending on the kind of use and sometimes on the manner in which it is carried out.

Prohibitive impacts involve permanent changes in the environment and thereby prohibit all uses unable to cope with such changes. The geographical range of such impacts may be from the limited area in which they occur to an entire estuarine system, depending on the nature and size of the change. The impact may be temporary, if it is possible to return the environment to its original form, or it may be permanent.

Any use or activity requiring physical modification of the shoreline, marshes, or bottom of an estuarine system may have a prohibitive impact. Modification of water circulation also tends to be prohibitive when it has any conflicting impact. Examples of estuarine uses and activities generally having prohibitive impacts are navigation dredging, other dredging and filling, solid waste disposal, construction of bridges, dikes, jetties, and other structures, shoreline development, mining from the estuarine bottom, and flow regulation.

Some estuarine uses may restrict estuarine use for other purposes but do not automatically exclude other uses. These are those activities which do not require a permanent modification of the estuarine system; they generally include those uses directly involved with the estuarine waters and other renewable resources.

Restrictive impacts may involve damage to water quality, living organisms, or aesthetic quality; such impacts may also result from the exclusive appropriation of space. The key feature of uses which cause restrictive impacts is that they may, with proper management, be carried out simultaneously with other uses.

Any kind of municipal or industrial waste discharge may have a restricted impact and often does. Commercial fishing, recreation, and water supply are the major uses restricted by pollution from liquid waste discharges.

Some kinds of commercial fishing require the use of trawls or the setting of traps or nets that must be left for some time. The use of such devices restricts other uses while the devices are in place, but there is no permanent appropriation of estuarine waters or space. The major conflict is with recreation in that recreational boating must be excluded from areas where fishing gear is near the surface.

Where there is conflict, the scene is set for trade-off, i.e., a willing substitution of one activity for another. The scene is equally set for uncompensated damage where one user group precludes the activities of a second unrelated user group but does not reimburse them for damage. Actual documented examples of use damages are difficult to find. One major reason is the basic fact that has permeated much of the discussion of economic and social values: Many estuarine values are not quantifiable. While damages to a commercial enterprise, such as commercial fishing, can be quantified in terms of the economic loss, the essentially intangible values of recreation and estuarine habitat are difficult to measure.

Recreational loss would have to be measured in terms of how many people don't swim or go boating in the Potomac River because it is polluted. It is far easier to find out how many people do go there even if it is polluted; even these values are hard to find.

The value of estuarine habitat is just as difficult to establish. There are now about 5.5 million acres of important estuarine marsh and wetland habitat remaining in the estuarine zone of the United States. Perhaps

each acre is not valuable by itself, but the total habitat is irreplaceable.

Use damage is not a necessary feature of civilization in the estuarine zone, but use conflicts will continue to exist as more and more demands are made on the natural environment. The ability of any management authority to prevent use damage and to resolve use conflicts depends not only upon its institutional composition and legal authority, but also upon the social, economic, and biophysical characteristics of the estuarine management unit within which its authority is exercised.

The analyses of social and economic values of the estuarine zone examined concurrently with the similar analyses of use conflicts, pollutional effects, and use damages form the basis for resolving use conflicts through the application of technical knowledge, i.e., technical management.

The primary objective of technical management is to accommodate the needed and desired uses of any estuarine management unit within that system without overall damage to the biophysical environment. The ability to achieve this objective depends on the boundaries of the management unit and upon the means available for resolving both prohibitive use conflicts and restrictive use conflicts.

The impact of the social and economic requirements of civilization on the natural estuarine environment is the technical problem with which management must deal, and effective control of this impact can

be maintained only if both the major sources of damage and the geographic range of their influence are subject to unified control.

An estuarine management unit, therefore, should consist not only of the estuarine waters, bottoms, and associated marshlands; but it should also include all of the shoreline surrounding the estuarine waters themselves and as much of the adjoining land as is necessary to regulate the discharge of wastes into estuarine waters.

Allocation of part of the estuarine resource for an exclusive single-purpose use is a necessary fact of estuarine management. The shoreline is a necessary location for shipping docks and for swimming beaches, but they cannot both occupy the same place on the shoreline. Similarly, frequently dredged channels and oyster beds cannot occupy the same space at the same time. Resolution of such conflicts can be achieved by allocation of adequate space to each use through whatever institutional mechanism is established.

The evaluation of the effects of prohibitive uses on the estuarine environment is probably the most difficult problem currently facing technical management. The immediate and obvious effects of the habitat loss associated with such uses can be measured and described fairly easily, but the ultimate results of the modification of water movement patterns and flushing characteristics can only be estimated in general terms.

In nearly every problem associated with prohibitive use conflicts, however, the area of primary concern is the effect on the estuarine ecosystem of any physical modifications proposed; the limitations of knowledge mentioned above, therefore, present a critical problem in present efforts to resolve prohibitive use conflicts.

A more difficult problem arises where there is involved a massive dredge or fill operation with its concomitant immediate effect on the ecosystem. When such modifications are a necessary or desirable development of the environment it may be necessary to forego the habitat use; however, in many cases it may be possible to create new, equivalent habitat in a different part of the management unit, or it might be possible to restore part of the damaged environment.

While the resolution of prohibitive use conflicts requires the abandoning of one use in favor of another, the potential for carrying out any modifications necessary so as to increase habitat value as well as economic value should be a key factor in the resolution of such problems.

Disposal of liquid wastes to the estuarine environment is the major restrictive use impact of the socioeconomic environment. This use conflict can be resolved completely either by treating all wastes to such an extent that they do not interfere with any other uses or else removing them entirely from the environment.

Technology exists to provide thorough treatment for nearly every kind of municipal and industrial waste, and there is no reason not to provide treatment sufficient to protect the environment from damage and to permit other uses. Treatment requirements for different wastes may vary from place to place according to local conditions, but damage to the environment and restriction of other uses can be prevented.

Water quality standards have been set and are now being implemented in all the coastal states. These standards are the foundation upon which the effective control of estuarine pollution rests, and they provide the framework within which technical management can effectively operate.

As pointed out earlier in this chapter, however, estuarine waters even in busy harbors are used for recreational purposes by those who cannot afford to go elsewhere, regardless of whether the waters are safe for body contact or not. Also the role of the estuarine zone as a nursery for some fish, passage for others, and a residence for still more is readily apparent although its full implications in the energy conversion chain are not understood. For these reasons the long-range achievable water quality goal of estuarine management should be to keep all waters safe for direct contact by humans and also usable as a fish and wildlife habitat.

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As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's "Department of Natural Resources."

The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States — now and in the future.